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CHAPTER 5

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WATER SUPPLY ASHORE

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WATER SUPPLY ASHORE

Section I. WATER SUPPLIES

5-1. The Problem of Pure Water

(1) A hygienical'y safe and continuously dependable water supply is one of the vital necessities of life. Water, like other natural resources, is procured as a raw material, manufactured into a commodity suitable for use, and distributed to places of consumption. In North American cities the design of waterworks and their sanitary control by public health agencies have been so developed that water supplies today are pure and abundant. This has been accomplished only at great expense, and the safety of these municipal supplies is ensured by the erection of multiple barriers against the agencies of disease and by uninterrupted vigilance against the development of sanitary hazards. It is the responsibility of the Navy Medical Department to make sure that barriers to the spread of waterborne disease in the Department of the Navy are adequate.

(2) Actually, drinking water must be free of disease-producing organisms, poisonous chemicals, and objectionable color, odor, or taste. All untreated water is considered unsafe until approved by a medical officer or his designated representative.

5-2. Sources of Water

(1) Water for naval stations in the United States is often purchased from a nearby municipality. Since this is normally safe water, the water sanitation measures on the station are directed toward prevention or discovery of defects in the distribution system which might lead to contamination of the product. Where municipal supplies are not available or are inadequate, the Department of the Navy builds and operates the complete system, which includes collection, purification, and distribution works. Protection of the source and control of purification then assume an importance equaling that of preventing recontamination during distribution.

(2) The sources that may be utilized are rainwater, ground water, surface water, or sea water. Ground water is commonly preferred, but is an unreliable source because of the great uncertainty as to the quantity and quality of water that will be continuously available. Surface water is more generally abundant and is more susceptible to quantitative and qualitative study; so it is used for most large supplies. Rainwater and sea water are used at advanced bases when surface and ground sources are inadequate. The type of purification required depends on the quality and uses of the water, and may vary from simple chlorination to elaborate treatment to remove minerals as well as bacteria and other organisms. The water purification works in permanent stations are similar to municipal plants. Equipment for advanced bases, on the other hand, is especially designed for mobility and simplicity of operation.

5-3. Quantities of Water Required

(1) The per capita consumption on shore stations depends on the climate, the standard of living maintained, and the extent to which water is used for industrial operation. On established bases with adequate bathing and laundry facilities, water consumption for all ordinary uses averages from 75 to 150 gallons per capita daily (god). A figure of 100 god may be remembered as typical. To this amount must be added the quantities required for the operation of water-consuming industries or for supplying the fleet. The needs for fire fighting, where supplied by the potable water system, are filled from stored reserves by means of pumping facilities. Stored water also compensates for the continual fluctuations in demand, thus making possible the uniform and economical operation of pumps and treatment works. The distribution system is designed to provide for peak quantities, which may exceed the average by several hundred percent, and to supply large quantities of water for fire fighting where the potable supply is used for this purpose.

(2) At advanced bases, water consumption generally reflects a compromise between a desirable abundance and a practical minimum for overseas operations. Rainwater and sea water are used at

advanced bases when surface and ground sources are inadequate. Water-treatment equipment is especially designed for mobility and simplicity of operation. The amount of water provided at well-developed advanced bases is usually approximately 50 gallons per capita daily. The quantity is decreased as the supply difficulties increase. Efforts are made to provide at least 25 god, but under actual combat conditions or at newly established bases only a fraction of this amount may be made available. Where distillation is the primary source of fresh water supply, 10 god is allowed. The minimum daily allowance of water in temporary camps and on advanced bases is 5 god. When the supply is limited to this amount, little if any potable water can be used for laundry or bathing. Minimum water requirements of advanced-base medical facilities are established at 50 gallons per medical treatment bed per day.

(3) In the field, the uses of water are apt to be restricted to those that are absolutely necessary. One gallon per man per day may be taken as the absolute minimum: 1½ quarts for drinking between meals, 3½ quarts for cooking and for drinking at meals. Two gallons per man should be considered the desirable minimum under adverse conditions. It has been established that there is no such thing as acclimatization to insufficient amounts of water. The water requirements of the human body are as absolute as those of a steam locomotive in that water consumption can be reduced only at the sacrifice of energy output. Furthermore, the desire for water rises sharply during periods of nervous strain. When under fire or in actual combat, men consume large quantities of water. If safe water or the means of purification are not available, the danger of drinking contaminated water is greatly increased during such periods. Thus, the provision of an abundant supply is a positive measure in the prevention of waterborne disease.

(4) Occasionally it may be necessary to provide water for animals or vehicles from the supply of potable water, but this usually does not present too great a problem, since the quantity will vary from 10 gallons per horse per day to 0.5 gallon per vehicle per day under desert conditions.

5-4. Essential Phases of Water Sanitation

(1) Water sanitation measures may be divided into the following categories:

(a) Selection of a raw-water source of good quality and one which is subject to reasonable protection from severe contamination. When water is readily available in an area and all sources are free of unusual impurities, the following rules should guide in selecting the source:

(1) In populated areas, use established public systems to the fullest extent consistent with the quality and ease of procurement.

(2) Use existing springs or wells next. The quality of water from these sources is usually better than from surface sources.

(3) If public or ground-water sources are not readily available, use surface-water sources such as rivers, streams, lakes, or ponds.

(4) When other sources are not available, dig wells to use ground-water sources. Development of new ground-water sources is not practical for troops on the move. For rear-echelon units, a ground-water source is usually best, especially in areas where surface-water sources are highly contaminated as, for example, in China, the Philippines, India, Japan, and other parts of Asia.

(5) As a last resort, when no fresh water source can be found, use distillation to purify sea water.

(b) Design of supply and distribution works to exclude contamination by eliminating all connections or openings through which nonpotable water might be pumped, sucked, diverted, or flooded into the potable water system.

(c) Provision of adequate and well-designed and maintained water purification facilities.

(d) Maintenance of proper operating and laboratory control of purification processes.

(e) Proper disinfection of all new pipelines and equipment and of all lines that have been opened for repair or alteration.

(f) Routine analytical checks on the potability of water to discover sanitary defects, supplemented by prompt and positive corrective action when indicated.

(g) Periodic inspections of sources, facilities, and practices to ensure the effectiveness of water sanitation. Failure to carry out any of the above measures properly may permit, sooner or later, the occurrence of that unfortunate combination of circumstances that produces waterborne epidemics.

5-5. Responsibility for Water Supply

(1) Where water-supply systems are concerned, the Bureau of Medicine and Surgery determines standards of environmental sanitation and other measures for safeguarding the health of naval personnel. The Bureau of Yards and Docks, the Marine Corps, and other cognizant bureaus comply with requirements of the Bureau of Medicine and Surgery and, so far as practicable, with State and local health and sanitation laws and ordinances. The bureau having management control of a shore activity where water-supply systems are located sponsors all projects in connection therewith. The Bureau of Yards and Docks is responsible for planning the structural features and for determining the character and adequacy of construction materials used for water-supply systems. In designing and constructing such a system, the Bureau of Yards and Docks provides facilities capable of meeting the

water requirements of the management-control bureau.

(2) The commanding officer is responsible for all phases of water supply. On continental and overseas shore stations, he is assisted by the public works officer or maintenance officer and medical officer. At Navy installations the public works officer is responsible for the design, construction, operation, and maintenance of the waterworks. At Marine Corps managed installations the maintenance officer is responsible for the operation and maintenance of the waterworks. The medical officer, assisted by his sanitation officer or environmental sanitation technicians, has the responsibility of advising when any phase of water sanitation is unsatisfactory and of recommending corrective measures. Under normal conditions, adequate protection of water quality can be obtained through cooperation of the medical officer and the public works officer or maintenance officer. It is wise, however, to confirm recommendations and actions in written communications to the commanding officer.

(3) The medical officer's responsibility for water supply in the field and on advanced bases varies greatly with the situation. During the initial phase of amphibious operations, each unit may either carry its own water or depend on local supplies disinfected in Lyster bags and canteens. The responsibility for the adequacy and safety of the water under these conditions falls largely on the unit medical officer. He must take part in initial plans for operations and arrangements for supplies and must indoctrinate all hands in the fundamentals of water sanitation and water discipline. The unit commander may depend upon the recommendations of the medical officer in locating sources of water and supervising its treatment and distribution. When filtration or distillation equipment has been brought in by the Marine engineers or by the construction battalions, the responsibility for water treatment shifts to these organizations, thus reducing the need for such close supervision by the medical officers or their representatives. Later on, when the advanced base has been well established, the normal division of responsibility between the public works or engineer officer and the medical officer develops.

(4) Satisfactory water sanitation in the field rests almost entirely on thorough planning and preparation. All unanticipated problems must be solved on the spot. A report of difficulties or failures may, however, lead to improvements in preparations for later operations.

5–6. Chlorine Residuals in Water Supplies

(1) Six major variables have been shown to affect the efficacy of chlorine disinfection:

(a) the types and concentrations of the chlorine form present,

(b) the equilibrium relationships between co-existent chlorine forms (governed largely by the pH of the water),

(c) the type and density of organisms (virus, bacteria, protozoa, helminth, etc.) and their species resistivity to chlorine,

(d) the time of contact of the organism with the chlorine,

(e) the temperature of the water, as it determines both the rate of reaction of chlorine compounds and the rate of kill of organisms, and

(f) the concentration of substances whose rapid oxidation by chlorine is manifested as a "chlorine demand."

(2) It is generally accepted that, of the water-borne diseases, those whose causative organisms are bacteria are the most readily susceptible to chlorine disinfection. On the other hand, the cysts of *Endamoeba histolytica* are the most resistant. Therefore, two parallel recommendations for residual chlorine are made, the lower one sufficient for bactericidal purposes and the higher one sufficient for cysticidal purposes. The former should be routinely used for all water supplies where only waterborne bacteria are likely to be present. The latter should be instituted as the prevailing chlorination practice wherever epidemiological evidence indicates endemicity of nonbacterial waterborne diseases such as amebiasis and infectious hepatitis. Such information as exists suggests that cysticidal residuals are also virucidal.

(3) Because of the well-documented rapidity of disinfection by free available chlorine as compared with the slower kill effected by the chloramines (combined available chlorine), a distinction must be made between the required concentrations of chlorine and chloramines. Chlorination as a free residual should be practiced as widely as possible.

(4) Figure 5–1 shows a single line for bactericidal chlorine residuals over the temperature range 0°–25° C. The same is true for bactericidal chloramine residuals. Also shown on figure 5–1 are curves for cysticidal residual for free chlorine for the low and normal temperature ranges. Figures 5–2 (2°–5° C.) and 5–3 (22°–25° C.) are supplementary charts indicating the length of contact time required for cysticidal kill with stated residuals at stated pH values.

(5) It is emphasized that the only true guide to proper chlorination is the bacteriological quality of the finished product. The adoption and maintenance of minimum chlorine residuals should not minimize and can never replace bacteriological analysis as the true measure of potability. Only during actual or potential outbreaks of waterborne diseases is the application of chlorine residual throughout the entire water-distribution system fully justified. During such periods the residual concentration should be maintained at levels higher than those maintained in routine practice.
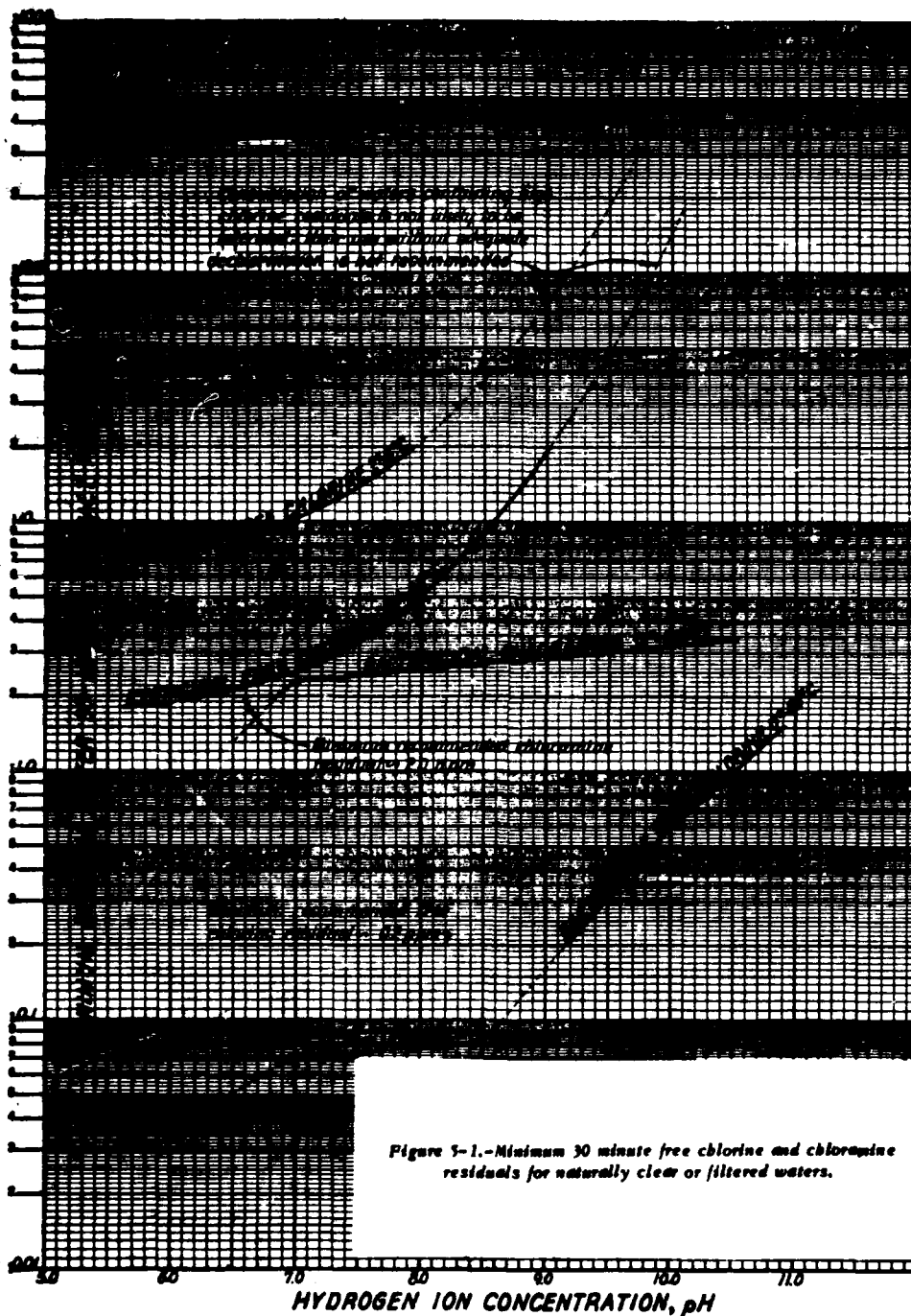
*Figure 5-1.-Minimum 30 minute free chlorine and chloramine
residuals for naturally clear or filtered waters.*

HYDROGEN ION CONCENTRATION, pH

Figure 5-2.-Minimum contact time required for free chlorine residual to effect complete kill of Endamoeba histolytica in naturally clear or filtered waters at 2° - 5° C.

HYDROGEN ION CONCENTRATION, pH
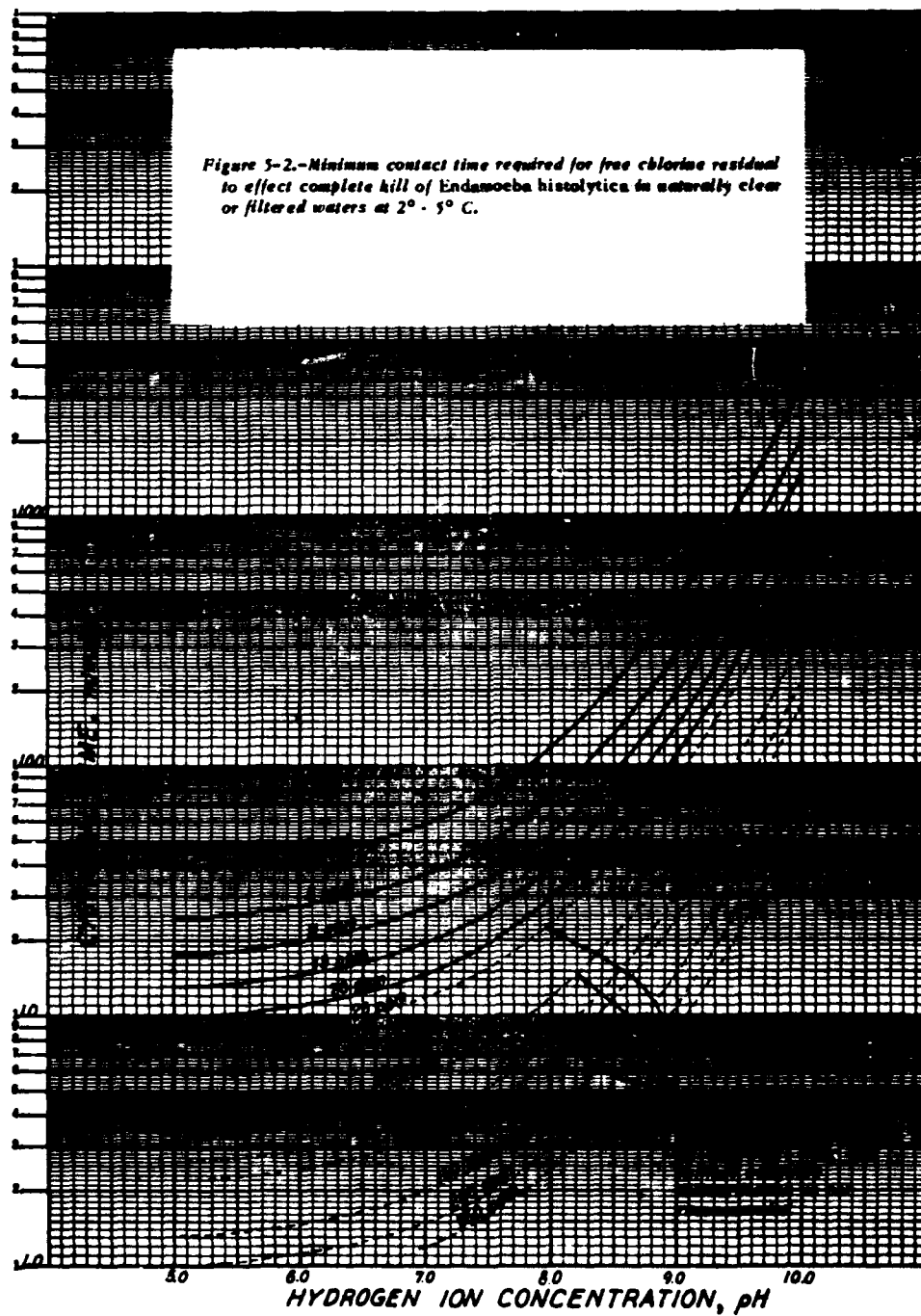
Figure 5—3.—Minimum contact time required for free chlorine residual to effect complete kill of Endamoeba histolytica in naturally clear or filtered waters at 22° - 25° C.

HYDROGEN ION CONCENTRATION, pH

Section II. WATER SOURCES

5-11. Types of Water Sources

(1) A satisfactory water source is one with a natural supply of water large enough to supply all needs of using troops, and of such quality that it can be readily purified by available equipment. Sources are classified as follows:

    (a) Rainwater: catchment.

    (b) Ground water: wells and springs.

    (c) Surface water: streams, ponds, lakes, and rivers.

    (d) Sea water: distillation.

    (e) Dew: condensation on cool surfaces.

    (f) Vegetation: coconut, wild pineapple, and cactus.

    (g) Snow and ice: heat.

(2) The types of water sources most frequently found in various climates are listed below:

    (a) Humid, temperate climate: surface and ground water.

    (b) Arid climate: ground water and minor sources.

    (c) Tropical climate: surface water, ground water, and minor sources.

    (d) Coral islands: ground and sea water.

    (e) Arctic climate: surface water, ice, and snow.

5-12. Rainwater

(1) Because of its freedom from minerals (softness), rainwater is frequently useful for cooking, bathing, and for laundry use and boilers. However, it lacks palatability and may contain dissolved gases as well as dust particles and bacteria swept from the air. As a source of fresh water it is important only on small islands or in isolated places where ground water is salty and surface water inadequate. Under these conditions, where the requirements are small and precipitation heavy, rain may furnish an adequate supply for all uses. In many places it will prove valuable in augmenting the supplies from other sources. Rainwater, however, is subject to the same quality controls as other sources of drinking water.

(2) Rainwater is collected from the usual type of impervious surfaces such as roofs, concrete pavements and aprons, and barren rocks or from areas rendered impervious by suitable paving.

The volume derived depends on the catchment area and on the amount of rainfall. A rule of thumb for the volume in gallons that may be recovered from an impervious surface equals the horizontal area in square feet multiplied by one half the rainfall in inches. In order to make this amount of water available, storage must be provided to hold water for use during the periods between rains.

Rainwater may be stored either above or below ground in any convenient tank or container. Storing rainwater in underground cisterns reduces evapor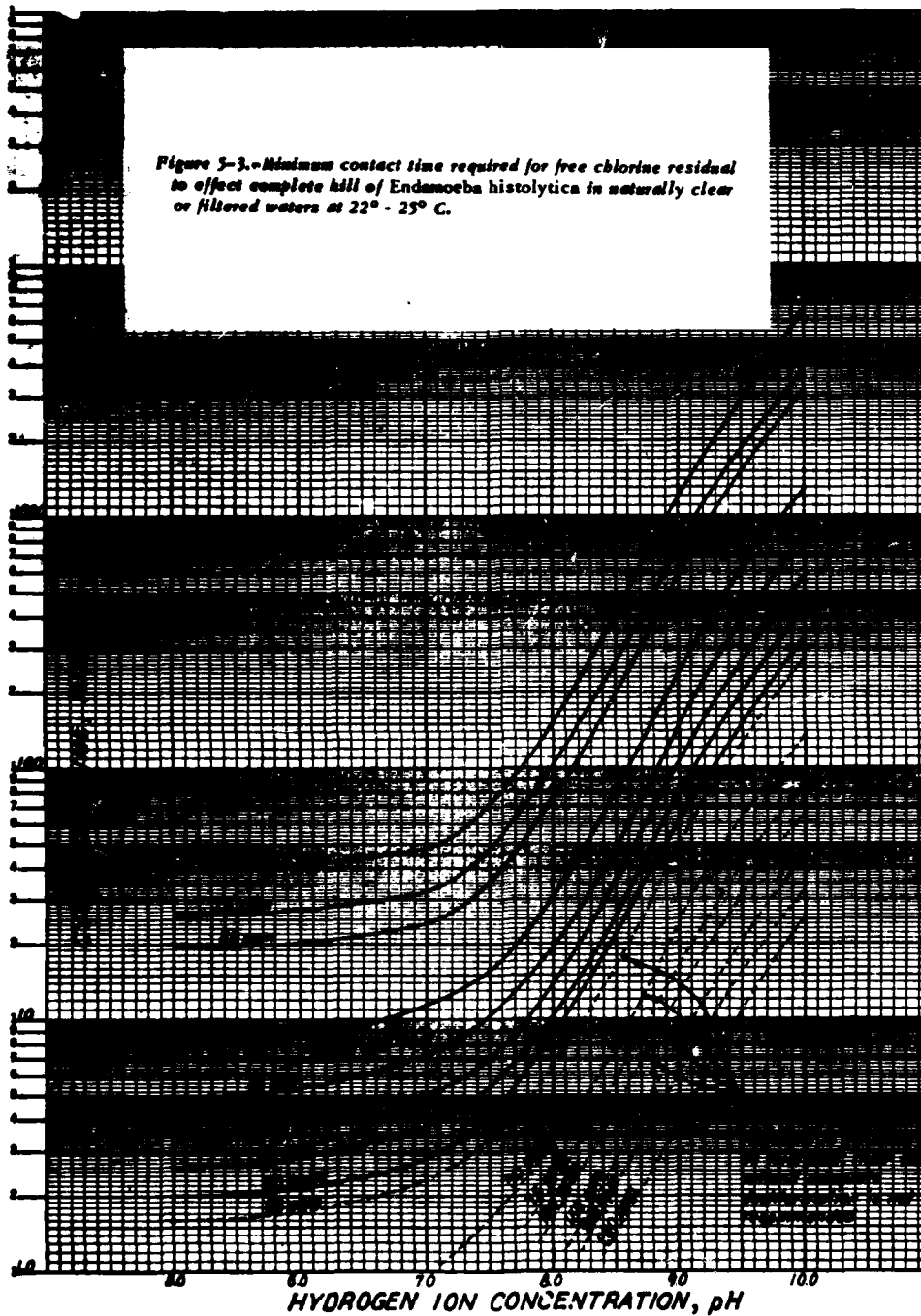ation and keeps the water cooler and consequently more palatable. Storage receptacles should be protected from dust and dirt, and from contamination by polluted surface or ground water. They should be covered or screened to prevent mosquito breeding or the entrance of vermin.

(3) The surfaces from which rain is collected are usually subject to contamination by birds, animals, and dust, and, if at ground level, by human wastes. The first rain which falls during a storm flushes these substances from the surface and consequently should be diverted to waste. To avoid any possibility of unsafe drinking water being provided, rainwater should always be considered unsafe and should be treated accordingly—by filtration, if possible, and always by chlorination so that the quality will conform to the standards established for drinking water from other sources.

5-13. Ground Water

(1) Water in the interstices of saturated earth and rock is known as ground water. The water table is the upper level of the zone of saturation or the level at which water stands in wells. The ground-water body is fed by infiltration of rain and melting snow and is depleted by flow from springs, withdrawals from wells, and seepage into swamps and streams. No more water can be continuously taken from the ground than that amount which enters by infiltration from the surface. The rate of lateral movement through the ground, and thus the rate of withdrawal from the wells, is governed by the porosity of the earth. Large yields of ground water are obtained from properly constructed wells penetrating beds of gravel and coarse sand or

creviced and cavernous rock. Wells in clay or dense unfractured rock yield little water. Artesian waters rise from porous strata overlaid by confining beds of impervious clay or rock.

(2) Fresh ground water on volcanic or coral islands usually occurs as a lens floating on the salt water. The flushing action of fresh accretions of rainwater from the surface and the elevation of the water table above sea level holds back the salty water. The recovery of this water is best accomplished by means of wells dug on high ground near the center of the island. If possible, the water should be removed at low tide by a skimming process or by multiple low yield wells which will prevent lowering the water table sufficiently to pull salt water up from below. Brackish water will appear in these wells if the level is drawn down to or below sea level for any considerable period of time. A broad shallow well in coral, a tunnel or gallery into volcanic rock, not extending below sea level, will prevent excessive drawing on the well.

(3) The quality of ground water is determined by the physical characteristics of the ground through which it passes, the surface topography, the land usage or environment, and the time of storage in the water-bearing formations that are unsuitable for the maintenance of bacterial life. The normal soil-percolation processes filter out suspended matter and bacteria, but at the same time add chemicals that sometimes require extensive treatment to eliminate. Bacterial activity in the soil removes organic matter and replaces the oxygen with carbon dioxide generated by decomposition. The carbon dioxide renders the water weakly acid, and in the presence of limestone, coral, or other soluble rock the mineral content of ground water may rise to high levels. In areas where cavernous limestone or volcanic rock are near the surface, water may enter through sinkholes, fissures, and other openings. This water retains the objectionable characteristics of surface water, such as high turbidity and bacterial content, and its character is little improved by movement through open passages in the rock. The presence of free-flowing channels in the ground or a rise in turbidity of ground water following rains are danger signals.

(4) Many wells are subject to pollution either through open formations in the ground, by leakage from the surface down outside the casing, through perforations in the casing as corrosion progresses, or through the top of the casing not properly fitted with an adequate well seal. The degree of pollution, of course, depends upon the construction of the well, the depth of the well, the type of pumping equipment, and the strata of the subsoil in which the well is constructed. Well water, therefore, should be adequately chlorinated.

5-14. Surface Water

(1) Surface-water supplies are obtained from rivers, streams, lakes, ponds, and pools. Since the amount and quality of water available from a surface source varies widely as the season changes, it may be necessary to investigate the history and habits of a stream or lake before placing too much dependence upon it. Elaborate hydrological studies should precede the choice of the source for a large supply.

(2) Surface sources are supplied by runoff following storms and by the flow or seepage of water from the ground. During rainy weather streams are turbid and polluted with material washed from the ground surface. Because of the rapid movement and interference with natural purifying processes during floods, sewage and other contamination may be carried for long distances. Dry-weather flow consists primarily of ground water; so streams are clear and more highly mineralized during dry periods. Self-purification processes are most active in a clear stream, and, though the dilution of sewage and other wastes is reduced during dry weather, the recovery of stream purity may take place in a relatively shorter stretch of channel. A normally sluggish stream is high in organic matter and may be odorous because of dense algae growths and the formation of sludge banks. Such streams are poorer sources for a water supply than are clear swiftly running streams, particularly those mountain streams and lakes remote from inhabited areas. However, little credence should be placed in arbitrary statements such as "running water purifies itself in 15, or 20, or 100 feet," because such a statement is misleading, as nothing is known of the amount of contamination, sedimentation, aeration, or dilution.

(3) Surface water must always be disinfected and should receive such additional treatment as the situation permits to render it free of turbidity, tastes, and odor. In areas where amebiasis is prevalent, all water should be filtered and chlorinated as described in art. 5-6 or, where this is impossible, should be either boiled or disinfected with iodine.

5-15. Sea Water

(1) The sea serves as the major source of water for the fleet. Ashore, it is utilized only in the absence of adequate fresh-water sources. Sea water contains up to 37,000 parts per million of dissolved salts which must be removed by distillation. Since shallow coastal water may carry considerable organic material and turbidity, or be polluted with oil or other wastes, it may be desirable to settle sea water before pumping it to stills located on the beaches. Advantage may be taken of natural filtration and the diluting effect of ground water by distilling water withdrawn from shallow wells located along the shore. Since distillation is an expensive

process, all available fresh-water sources should be fully utilized as soon as the military situation permits.

5-16. Dew

(1) Although of insignificance as a source of water for field units, the condensed dew on cool surfaces has been collected and used by individuals for survival in cases of extreme emergency and hardship.

5-17. Vegetation

(1) Coconuts, wild pineapple, and certain species of cactus have been utilized for survival by individuals and small units in emergencies.

5-18. Snow and Ice

(1) While almost any place in the Arctic will be near water in one form or another at sometime of the year, the provision of an adequate and safe-water supply for more than 50 men is likely to be a major problem. Potential sources are streams, lakes and ponds, glaciers, fresh-water ice, last year's sea ice, and snow. Freshly frozen sea ice is salty, but year-old sea ice has the salt leached out. It is well to test freshly frozen ice when looking for water. In some areas where tidal action and currents are small, there is a layer of fresh water lying on top of the ice. The lower layers may still contain salt. In some cases, this layer of fresh water may be 2 to 4 feet in depth. If possible, get water from running streams or lakes instead of melting ice or snow. Be sure that the stream or lake selected is deep enough to prevent freezing to the bottom. Melting ice or snow wastes fuel. In winter cut a hole through the ice of a stream or lake to get water. Cover the hole with snow blocks or loose snow to retard freezing. In extremely cold weather break the water hole open at frequent intervals. Mark the water hole with a stick or other marker which will not be covered by drifting snow. Water is abundant during the summer in lakes, ponds, or rivers. The milky water of a glacial stream is not harmful. Let it stand in a container until the coarser sediment settles. REMEMBER: Winter or summer, purify water from ponds, lakes, or streams by boiling or by chemical treatment.

(2) When water is not available, it will be necessary to get water by melting snow or ice. To save fuel, use ice or the most compact snow available. Gather snow only from areas which have not been contaminated by men or animals. Ice sources are frozen rivers or ponds, glaciers, icebergs, or old sea ice. Old sea ice is rounded where broken and is likely to be pitted and to have pools on it. Its underwater part has a bluish appearance. Fresh sea ice has a milky appearance and is angular where broken. Avoid burning the bottom of a melting pot by "priming." Place a small quantity of water in the bottom of the pot and add snow gradually. If water

is not available, hold the pot in the hand near the stove and melt a small quantity of snow in the bottom of the pot before filling it with snow. Compact the snow in the melting pot and stir it occasionally to prevent burning the bottom of the pot. Keep pots of snow or ice on the stove when not cooking so as to have water available when needed. Pile snow or ice to be melted just outside the tent and bring it in as needed. Purify the water by boiling or by chemical treatment.

(3) An excellent informational series of operational briefs is given in reference 2.

5-19. Selection of Source

(1) The choice of a water source is influenced by quantity, quality, ease of procurement, ease of purification, and other factors. Supplies for permanent shore stations are usually selected on the basis of detailed engineering studies of all reasonably promising sources. However, during military operations, a hasty estimate of quality and adequacy of a source may be all that is possible. A water reconnaissance is usually made to find and look over available sources and to select that which appears to be most suitable.

(2) The considerations of quality which merit study are:

(a) Freedom from contamination by sewage and other wastes and from enemy pollution by chemical, biological, or radiological materials.

(b) Freedom from turbidity, color, and taste.

(c) Freedom from excessive amounts of organic and mineral substances.

(3) There is a tendency, based probably on recreational experience, to locate military camps along stream banks or close to shore even though the health hazards may be much greater in these areas than on high and dry ground not far distant. In planning camps and bases in the Tropics, too much importance should not be given to the convenience of locating near a source of water. The effort required to pipe or haul water to healthier sites may be insignificant when compared with the difficulty and expense of controlling insects in the swampy areas along a water course.

5-20. Recreational Use of Watersheds

(1) Frequently, because of public-relation considerations, the question of using watershed streams or reservoirs for recreational purposes, i. e., fishing, boating, picnicking, and bathing, will arise for local command decision. The most realistic decision will result in considering the presence or absence of an effective filtration process in the local water-supply system. The reservoir should not be used for recreational purposes if filtration is not a part of purification, and sedimentation resulting from storage in reservoirs followed by chlorination is the only safeguard provided.

Section III. WATER FROM MUNICIPAL SOURCES

5-21. Quality of Municipal Water

(1) Hygienically pure and esthetically pleasing water is supplied in practically all American communities having public water-supply systems. Water consumers have grown to expect a palatable as well as a safe water and are ready with complaints whenever water has a slightly unpleasant taste. With few exceptions, municipal supplies in the United States are palatable and meet the quality standards of the Department of HEW, Public Health Service. This situation does not prevail widely outside the United States. All water supplied from public systems abroad should be considered of doubtful quality and should be tested and, if necessary, disinfected.

5-22. Responsibility of the City

(1) When municipal water is purchased for a naval or Marine Corps installation, the city is under legal obligation to deliver water that is pure and safe from possible contamination. The city is not obliged, however, to deliver water containing a residual disinfecting agent. If free chlorine is used to disinfect water at the purification plant, maintenance of residuals at distant points in the system may be impossible without so charging the water with chlorine that it would be unfit for use in areas near the point of chlorination. When the ammonia-chlorine process is used, residual action may be maintained more easily, but disinfection is less certain because of the relative ineffectiveness of chloramines, which necessitates maintaining the chloramine residual at a much higher level.

(2) The city is responsible for protecting the purity of water throughout its distribution system. It is well recognized that cross-connections with polluted supplies constitute a danger to the health of the community. Police power regulations are, therefore, in force almost everywhere forbidding or controlling such cross-connections and giving representatives of the municipality the right to inspect points of possible cross-connections on the consumer's property and the right to discontinue the public supply when improper cross-connections are found.

(3) In order to assure the safety of the water, the city or other water-supply agency usually samples and tests the water with reasonable frequency at points distributed throughout the system, and, on request, supplies the results of these analyses to consumers. The city's waterworks system and its operating practices are normally open to inspection and review.

5-23. Responsibility of the Department of the Navy

(1) The Department of the Navy is responsible for the protection of the purity of the water during its distribution on its premises. It is further obligated to permit periodic inspections by representatives of the agency charged with protecting the public supply. The Department of the Navy is entitled to demand delivery to its premises of a pure, wholesome, and safe water and should carry out laboratory tests of water at the point of delivery when there is question as to the quality of water purchased. Conversely, when a Navy or Marine Corps installation provides water to a neighboring activity or community, the installation is responsible for maintaining standards as prescribed by the Public Health Service.

Section IV. ANALYSES AND STANDARDS

5-31. Water Analyses and Standards

(1) The term "safety" as applied to potable water indicates the degree of reliability of the measures used to assure a supply uniformly high in quality. The safety of a supply depends on the protection of the source; the purification processes used and the excellence of their design and operation; the proper design, construction, maintenance, and operation of pumping stations, reservoirs, and distribution systems; and the absence of cross-connections or other means whereby nonpotable water may enter the system. The safety of a water supply is judged by:

(a) Periodic surveys of all physical features of a water system and an investigation of operating maintenance practices; and

(b) Routine laboratory analyses of water quality.

(2) Two types of quality standards are used in water sanitation practice:

(a) Standards for certifying public supplies on the bases of numerous past laboratory analyses; and

(b) Standards for judging the current safety of a supply from the individual test results.

(3) The bacteriological examinations recognized as being of most value are:

(a) The count of total colonies developing on agar in 24 hours at 35° C. Plate counts, when regularly made, are useful in controlling water purification processes and in determining the current safety of a water supply. The mistake should not be made, however, of condemning the water on the basis of a high plate count alone, since water is costly and sometimes difficult to obtain. A far better policy is to recommend immediate chlorination. Bacterial growths not necessarily pathogenic, particularly in warmer climates, may be quite rapid, but are usually readily controlled by frequent and routine chlorination.

(b) The quantitative estimation of organisms of the coliform group. The test for the coliform group (art. 5-32) is the most significant because it affords the most nearly specific test for the presence of fecal contamination. Only this test is included in the bacteriological standards recommended by the Public Health Service.

(4) The results of routine bacteriological tests of samples of water cannot be regarded as providing complete or final information concerning the quality of the water. Bacteriological results must be considered in the light of information available concerning the sanitary conditions surrounding the source of any particular sample. Precise evaluation of the quality of a water supply can be made only when the results of laboratory examinations of the water are interpreted in the light of such sanitary data.

(5) The standards adopted by the Public Health Service for drinking and culinary water supplied by common carriers in interstate commerce are used throughout the United States for certification of water supplies and for judging the past performance of sanitation measures. *Public Health Service Drinking Water Standards, 1962*, PHS Publication No. 956, are now a part of the Interstate Quarantine Regulations. The numerical values specified in the *Public Health Standards* are such that communities with reasonably safe supplies can qualify to furnish water for common carriers. The reasoning behind the preparation of these Standards was that persons from such communities are entitled to be served, while on interstate travel, water of a quality equal to that of the water they receive at home. A lack of understanding of the background and purpose of the *Public Health Service Standards*

has lead to some criticism, particularly when an attempt has been made to use these standards for judging the significance of individual test results. APPENDIX A of this chapter is the appendix of *PHS Drinking Water Standards, 1962*, less reference data. This appendix contains background information used in developing the *1962 Drinking Water Standards*. (A copy may be obtained from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402—price 30 cents.)

(6) The Department of Defense has directed that the standards for water used for drinking and culinary purposes by the Department of the Navy will be those standards promulgated by the United States Department of HEW, Public Health Service, as may be modified by the Chief, Bureau of Medicine and Surgery, or as may be modified by competent authority for purposes of international agreement. The Naval Tripartite Standardization Agreement ABC-NAVY-STD-23 was promulgated by OPNAV Instruction 5711.9 dated 16 May 1958 and BUMED Instruction 5711.2 dated 30 January 1959, the object of which is to provide the United States Navy *, the Royal Navy and the Royal Canadian Navy assurance that drinking and culinary water delivered to each other's ships from installations under their cognizance meets certain minimum standards of quality.

(7) The membrane filter procedure for the bacteriological examination of water was developed in Germany during World War II. Following an extensive study of the application of this procedure to the routine examination of water supplies, the membrane filter technique was included as a tentative method in the tenth edition of the APHA *STANDARD METHODS for the Examination of Water and Wastewater*. With full consideration of the limitations of the membrane filter technique as discussed below, it is here designated a standard method for the bacteriological examination of water and sewage, and for related problems. It may be used for determining the potability of a given water after adequate parallel testing has demonstrated that it yields, for the particular water, information equal to that from the multiple-tube fermentation procedure relative to the sanitary quality of the water supply. Since 1955 the membrane filter procedure has been the subject of wide discussion and investigation. From the accumulated research data it may be concluded that:

(a) The membrane filter technique provides a means for improved control of water quality in water treatment plants and other laboratories since (1) it has a higher degree of precision (reproducibility) than the multiple-tube fermentation test; (2) it permits the examination of much larger volumes of sample than the multiple-tube test, with increased

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*Also applicable to Marine Corps installations.

sensitivity in coliform detection; and (3) definitive results are obtained in a shorter time than with the multiple-tube procedure.

(b) The membrane filter method permits field filtration of the sample and shipment of the filters to the laboratory on a preservative medium.

(c) The membrane filter technique may be applicable in disasters and in emergencies such as arise from broken water mains, where the time which elapses before results of examination are available is an important consideration in the prompt initiation of corrective treatments.

(d) The membrane filter test at present has definite limitations. There are areas of application not usually associated with potable water supplies where the method cannot be accepted as a satisfactory alternative to the multiple-tube fermentation technique:

1. In waters with turbidity due to algae or other material, clogging or filming of the filter will preclude the testing of a sufficiently large volume of sample to provide a reliable indication of coliform density and will interfere with the development of characteristic colonies of coliform bacteria during incubation.

2. In waters with a high density of noncoliform organisms, the ratio of membrane filter density estimates to MPN estimates will be excessively low. These discrepancies may be caused by specific characteristics of microorganisms in the sample, inhibitory action of the medium, or peculiarities of the water tested, such as the presence of heavy-metal ions, other toxic substances, or high natural temperatures.

(e) The field filtration modification of this technique is particularly valuable for routine control and field work.

5-32. Drinking Water Standards

(1) *Definition of Terms*—The following terms are defined for clarification in interpretation of the Standards.

(a) *Adequate protection by natural means* involves one or more of the following processes of nature that produce water consistently meeting the requirements of these Standards: dilution, storage, sedimentation, sunlight, aeration, and the associated physical and biological process which tend to accomplish natural purification in surface waters and, in the case of ground waters, the natural purification of water by infiltration through soil and percolation through underlying material and storage below the ground water table.

(b) *Adequate protection by treatment* means any one or any combination of the controlled processes of coagulation, sedimentation, absorption, filtration, disinfection, or other processes which produce a water consistently meeting the requirements of these Standards. This protection also

includes processes which are appropriate to the source of supply; works which are of adequate capacity to meet maximum demands without creating health hazards, and which are located, designed, and constructed to eliminate or prevent pollution; and conscientious operation by well-trained and competent personnel whose qualifications are commensurate with the responsibilities of the position.

(c) *The coliform group* includes all organisms considered in the coliform group as set forth in *STANDARD METHODS for the Examination of Water and Wastewater*, current edition, prepared and published jointly by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation. (Definition of the coliform group in the eleventh edition: The coliform group includes all of the aerobic and facultative anaerobic, Gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35° C.)

(d) *Health hazards* mean any conditions, devices, or practices in the water supply system and its operation which create, or may create, a danger to to the health and well-being of the water consumer. An example of a health hazard is a structural defect in the water supply system, whether of location, design, or construction, which may regularly or occasionally prevent satisfactory purification of the water supply or cause it to be polluted from extraneous sources.

(e) *Pollution*, as used in these Standards, means the presence of any foreign substance (organic, inorganic, radiological, or biological) in water which tends to degrade its quality so as to constitute a hazard or impair the usefulness of the water.

(f) *The standard sample* for the bacteriological test shall consist of:

1. For the bacteriological fermentation tube test, 5 standard portions of either:
   a. 10 milliliters
   b. 100 milliliters

2. For the membrane filter technique, not less than 50 milliliters.

(g) *Water supply system* includes the works and auxiliaries for collection, treatment, storage, and distribution of the water from the sources of supply to the free-flowing outlet of the ultimate consumer.

(2) *Source and Protection.*

(a) The water supply should be obtained from the most desirable source which is feasible, and effort should be made to prevent or control pollution of the source. If the source is not adequately protected by natural means, the supply shall be adequately protected by treatment.

(b) Frequent sanitary surveys shall be made of the water supply system to locate and identify health hazards which might exist in the system.

(c) Approval of water supplies shall be dependent in part upon:

1. Enforcement of rules and regulations to prevent development of health hazards;

2. Adequate protection of the water quality throughout all parts of the system, as demonstrated by frequent surveys;

3. Proper operation of the water supply system under the responsible charge of personnel whose qualifications are acceptable to the Bureau of Yards and Docks, the Bureau of Ships, or the Marine Corps, as appropriate;

4. Adequate capacity to meet peak demands without development of low pressures or other health hazards; and

5. Record of laboratory examinations showing consistent compliance with the water quality requirements of these Standards.

(3) *Bacteriological Quality.*

(a) *Sampling.*

1. Compliance with the bacteriological requirements of these Standards shall be based on examinations of samples collected at representative points throughout the distribution system. The frequency of sampling and the location of sampling points shall be established jointly by the station medical officer and the public works officer, or other competent authority, after investigation of the sources, method of treatment, and protection of the water concerned.

2. Minimum numbers of samples to be collected from the distribution system: One (1) sample at varying points in the distribution system serving up to 7,500 persons, weekly. One (1) additional sample for each additional 500 persons, or fraction thereof, monthly. One (1) sample of the effluent at a treatment plant or chlorination station, monthly. Sampling points shall be scheduled to cover the entire system. It is recommended that more frequent samples be collected for bacteriological analysis.

3. Daily samples collected following a bacteriologically unsatisfactory sample as provided in art. 5–32(3)(b) shall be considered as special samples and shall not be included in the total number of samples examined. Neither shall such special samples be used as a basis for prohibiting the supply, provided that: (1) When waters of unknown quality are being examined, simultaneous tests are made on multiple portions of a geometric series to determine a definitive coliform content; (2) Immediate and active efforts are made to locate the cause of pollution; (3) Immediate action is taken to eliminate the cause; and (4) Samples taken following such remedial action are satisfactory.

(b) *Limits.*

1. The presence of organisms of the coliform group as indicated by samples examined shall not exceed the following limits:

a. When 10 ml. standard portions are examined, not more than 10 percent in any month shall show the presence of the coliform group. The presence of the coliform group in 3 or more 10 ml. portions of a standard sample shall not be allowable if this occurs:

(1) In 2 consecutive samples;

(2) In more than 1 sample per month when less than 20 are examined per month; or

(3) In more than 5 percent of the samples when 20 or more are examined per month.

When organisms of the coliform group occur in 3 or more of the 10 ml. portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least 2 consecutive samples show the water to be of satisfactory quality.

b. When 100 ml. standard portions are examined, not more than 60 percent in any month shall show the presence of the coliform group. The presence of the coliform group in all 5 of the 100 ml. portions of a standard sample shall not be allowable if this occurs:

(1) In 2 consecutive samples;

(2) In more than 1 sample per month when less than 5 are examined per month; or

(3) In more than 20 percent of the samples when 5 or more are examined per month.

When organisms of the coliform group occur in all 5 of the 100 ml. portions of a single standard sample, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least 2 consecutive samples show the water to be of satisfactory quality.

c. When the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed 1 per 100 ml. Coliform colonies per standard sample shall not exceed 3/50 ml., 4/100 ml., 7/200 ml., or 13/500 ml. in:

(1) Two consecutive samples;

(2) More than 1 standard sample when less than 20 are examined per month; or

(3) More than 5 percent of the standard samples when 20 or more are examined per month.

When coliform colonies in a single standard sample exceed the above values, daily samples from the same sampling point shall be collected promptly and examined until the results obtained from at least 2 consecutive samples show the water to be of satisfactory quality.

(4) *Physical characteristics.*

(a) *Sampling.* The frequency of sampling shall be jointly established by the station medical officer and the public works officer. Under normal circumstances samples shall be collected one or more times per year from representative points in the dis-

tribution system and examined for turbidity, color, threshold odor, and taste.

(b) *Limits.* Drinking water should contain no impurity which would cause offense to the sense of sight, taste, or smell. Under general use, the following limits should not be exceeded:

Turbidity ------------------------------- 5 units
Color ------------------------------------ 15 units
Threshold Odor Number ------------ 3

(5) *Chemical characteristics.*

(a) *Sampling.*

1. The frequency of sampling shall be jointly established by the station medical officer and the public works officer. One (1) complete chemical analysis of the water supply shall be made annually, the following conditions applying:

a. If the supply is treated by the activity by filtration or softening, both raw and treated water are analyzed.

b. If the supply is from wells, water from each well is analyzed.

c. When experience indicates that the water quality (chemical) is stable, the requirements of one (1) analysis annually may be reduced to one (1) analysis bi-annually; and of one (1) analysis from each well to one (1) composite sample from all wells, by competent authority.

2. If however, there is some presumption of unfitness because of the presence of undesirable elements, compounds, or materials, periodic determinations for the suspected toxicant or material, should be made more frequently and an exhaustive sanitary survey should be made to determine the source of pollution.

(b) *Limits.* Drinking water shall not contain impurities in concentrations which may be hazardous to the health of the consumers. It should not be excessively corrosive to the water supply system. Substances used in its treatment shall not remain in the water in concentrations greater than required by good practice. Substances which may have deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the system in a manner which would permit them to reach the consumer.

1. The following chemical substances should not be present in a water supply in excess of the listed concentrations where, in the judgment of the

Bureau of Yards and Docks, the Bureau of Medicine and Surgery, or the Marine Corps, other more suitable supplies are or can be made available.

Substance	Concentration in mg/l (ppm)
Alkyl Benzene Sulfonate (ABS)	0.5
Antimony (Sb)*	0.01
Arsenic (As)	0.01
Chloride (Cl)	250.
Copper (Cu)	1.
Carbon Chloroform Extract (CCE)	0.2
Cyanide (CN)	0.01
Fluoride (F)	(See 5-32(5)(b)3)
Iron (Fe)	0.3
Manganese (Mn)	0.05
Nitrate[1] (NO₃)	45.
Phenols	0.001
Sulfate (SO₄)	250.
Total Dissolved Solids	500.
Zinc (Zn)	5.

*Not contained in Drinking Water Standards but this limit was determined by the Public Health Service and the Bureau of Medicine and Surgery.
[1] In areas in which the nitrate content of water is known to be in excess of the listed concentration, the public should be warned of the potential dangers of using the water for infant feeding.

2. The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply:

Substance	Concentration in mg/l (ppm)
Antimony (Sb)*	0.05
Arsenic (As)	0.05
Barium (Ba)	1.0
Cadmium (Cd)	0.01
Chromium (Hexavalent) (Cr⁺⁶)	0.05
Cyanide (CN)	0.2
Fluoride (F)	(See 5-32(5)(b)3)
Lead (Pb)	0.05
Selenium (Se)	0.01
Silver (Ag)	0.05

*Not contained in Drinking Water Standards but this limit was determined by the Public Health Service and the Bureau of Medicine and Surgery.

3. *Fluoride.* When fluoride is naturally present in drinking water, the concentration should not average more than the appropriate upper limit in the following table I. Presence of fluoride in average concentrations greater than two times the optimum values in table I shall constitute grounds for rejection of the supply. When fluoridation (supplementation of fluoride in drinking water) is practiced, the average fluoride concentration shall be kept within the upper and lower control limits in table I.

Table I

Annual average of maximum daily air temperatures[1]	Recommended control limits— Fluoride concentrations in mg/l (ppm)		
	Lower	Optimum	Upper
50.0-53.7	0.9	1.2	1.7
53.8-58.3	0.8	1.1	1.5
58.4-63.8	0.8	1.0	1.3
63.9-70.6	0.7	0.9	1.2
70.7-79.2	0.7	0.8	1.0
79.3-90.5	0.6	0.7	0.8

[1] Based on temperature data obtained for a minimum of 5 years.

In addition to the sampling required by paragraph (5)(a) above, the fluoridated and defluoridated supplies shall be sampled in the frequency and manner prescribed in BUMED Instruction series 11330.

(6) *Radioactivity.*

(a) *Sampling.*

1. The frequency of sampling and analysis for radioactivity shall be determined by the station medical officer, public works officer, maintenance officer, or other competent authority after consideration of the likelihood of significant amounts being present. Where concentrations of Ra^{226} or Sr^{90} may vary considerably, quarterly samples composited over a period of three months are recommended. Samples for determination of gross activity should be taken and analyzed more frequently.

2. As indicated in article 5–32(5)(a), data from acceptable sources may be used to indicate compliance with these requirements.

(b) *Limits.*

1. The effects of human radiation exposure are viewed as harmful and any unnecessary exposure to ionizing radiation should be avoided. Approval of water supplies containing radioactive materials shall be based upon the judgment that the radioactivity intake from such water supplies when added to that from all other sources is not likely to result in an intake greater than the radiation protection guidance[1] recommended by the Federal Radiation Council and approved by the President. Water supplies shall be approved without further consideration of other sources of radioactivity intake of Radium-226 and Strontium-90 when the water contains these substances in amounts not exceeding 3 and 10 $\mu\mu$c/liter, respectively. When these concentrations are exceeded, a water supply shall be approved by the certifying authority if surveillance of total intakes of radioactivity from all sources indicates that such intakes are within the limits recommended by the Federal Radiation Council for control action.

2. In the known absence[2] of Strontium-90 and alpha emitters, the water supply is acceptable when

the gross beta concentrations do not exceed 1,000 $\mu\mu$c/liter. Gross beta concentrations in excess of 1,000 $\mu\mu$c/liter shall be grounds for rejection of supply except when more complete analyses indicate that concentrations of nuclides are not likely to cause exposures greater than the Radiation Protection Guides as approved by the President on recommendation of the Federal Radiation Council.

(7) *Recommended Analytical Methods.*

(a) Analytical methods to determine compliance with the requirements of these Standards shall be those specified in *Standard Methods for the Examination of Water and Wastewater,* Am. Pub. Health Assoc., current edition and those specified as follows.

(b) Barium—*Methods for the Collection and Analysis of Water Samples, Water Supply Paper No. 1454,* Rainwater, F.H. and Thatcher, L.L., U.S. Geological Survey, Washington, D.C.

(c) Carbon Chloroform Extract (CCE)—*Manual for Recovery and Identification of Organic Chemicals in Water,* Middleton, F.M., Rosen, A.A., and Burttschell, R.H., Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio, and *Tentative Method for Carbon Chloroform (CCE) in Water,* J. Am. Water Works A. 54:223–227, Feb. 1962.

(d) Radioactivity—*Laboratory Manual of Methodology, Radionuclide Analysis of Environmental Samples, Technical Report R59–6,* Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio; and *Methods of Radiochemical Analysis Technical Report No. 173,* Report of the Joint WHO–FAO Committee, 1959, World Health Organization.

(e) Selenium—*Suggested Modified Method for Colorimetric Determination of Selenium in Natural Water,* Magin, G. B., Thatcher, L. L., Rettig, S., and Levine, H., J. Am. Water Works Assoc. 52, 1199 (1960).

(f) Organisms of the coliform group—All of the details of techniques in the determination of bacteria of this group, including the selection and preparation of apparatus and media, the collection and handling of samples and the intervals and conditions of storage allowable between collection and examination of the water sample, shall be in accordance with *Standard Methods for the Examination of Water and Wastewater,* current edition, and the procedures shall be those specified therein for:

1. The membrane Filter Technique, Standard Test or

2. The Completed Test, or

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[1] The Federal Radiation Council in its Memorandum for the President, Sept. 13, 1961, recommended that "Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II ($\mu\mu$c/day of Radium-226 and 200 $\mu\mu$c/day of Strontium-90)."

[2] Absence is taken here to mean a negligible small fraction of the above specific limits where the limit for unidentified alpha emitters is taken as the listed limit for Radium-226.

3. The Confirmed Test, procedure with brilliant green lactose bile broth,[8] or

4. The Confirmed Test, procedure with Endo or eosin methylene blue agar plates.[8]

5-33. Interpretation of Results

(1) The standards for treated drinking water are based on the confirmed coliform test conducted on either five 10-milliliter samples or five 100-milliliter samples.

(2) The current safety of a water supply cannot be determined satisfactorily from individual test results. Unfortunately, the difficulty in judging the significance of a single bad sample and in deciding on a course of necessary action is so great that no uniform rules can be developed. Nevertheless, one of the most important reasons for testing water is to determine from day to day whether or not sanitation measures are functioning properly. Efficient filtration and chlorination should yield a water free from "presumptive coliforms." If a single positive tube occasionally appears in the five comprising a standard sample, no action is indicated other than a check to see that chlorine residuals have been continuously adequate. However, if several tubes are positive or if single positives appear frequently, chlorination should be stepped up; or if chlorination has been satisfactory, a search should be made for the source of trouble. A majority of positive tubes in consecutive samples would normally indicate a sufficiently serious breakdown in water sanitation to justify a careful investigation of the condition of the system, the water meanwhile being regarded as unsuitable for use unless boiled or heavily chlorinated.

(3) Well-operated purification plants produce water with a 24-hour 35° C. plate count averaging between 2 and 10 colonies per milliliter and rarely exceeding 50 colonies per milliliter. Plate counts exceeding a reasonable maximum require explanation. A limit of 200 colonies per milliliter is often used. Plate counts running into thousands of colonies per milliliter in water that has been chlorinated almost always indicate sanitary defects, even though tests for the coliform group are negative.

5-34. Fluoridation and Defluoridation of Water Supplies

(1) Research investigations conducted by the U.S. Public Health Service and others revealed that the incidence of dental caries in children of certain communities was reduced as much as 65 percent after the fluoride content of communal water supplies was adjusted to the optimum level.

(2) The Department of Defense endorses the adjustment of the fluoride content of communal water supplies at military installations, where dependent children are in residence, in conformance with accepted health practices.

(3) The desirability for adjustment of fluoride concentration in a water supply will depend on:

(a) Dependent children 16 years of age or younger being in residence on the station.

(b) The discrepancy between the material fluoride content of the station water being consumed by the children and the optimum fluoride content of the water.

(4) The optimum fluoride content of a water supply is a function of the ambient temperature to which the children are exposed, since water ingestion is directly related to the temperature. It has been determined that the mean maximum daily temperature for the geographic locale for a period of 5 years or longer is an acceptable measure of the ambient temperature for the purpose of controlled water fluoridation. Table I (Art. 5-32(5)(b)3) presents the acceptable water fluoride concentrations in relation to ambient temperature. Where the mean maximum daily temperature exceeds 90.5° F., a fluoride concentration of 0.7 p.p.m. should be maintained. Similarly, a concentration of 1.2 p.p.m. should be maintained where the mean maximum daily temperature is below 50° F.

(5) Mean maximum daily temperature data for most areas within the United States, Alaska, Puerto Rico, and many Pacific islands can be obtained from the U.S. Department of Commerce Weather Bureau stations in the vicinity. In other areas, the information may be obtained from meteorological data at military air stations or from other sources.

(6) The fluoride content of natural waters may be variable, particularly if a considerable proportion is drained from surface sources. Accordingly, the fluoride content of supplies obtained wholly or partially from surface waters must be determined from a series of samples taken during a period of minimum flow. Underground water supplies are subject to less variation and the fluoride content can be determined from 2 samples collected during a week. Where more than one well is involved, separate determinations must be made from each well. Procedures for water fluoride testing are described in a BUMED Instruction of the 11330 series.

(7) At stations where children 16 years of age or under regularly receive the major portion of their potable water requirements from the water supply system and the average fluoride content of the water varies by 20 percent or more over or under the optimum level, the institution of a project for adjustment of the fluoride content should be considered.

(8) Upon determination that adjustment is desirable, current instructions should be consulted for procedures to be utilized for institution of the appropriate program.

5–35. Laboratories

(1) Each command is responsible for performing bacteriological examination of water where trained personnel and adequate facilities are available. The advisory services of the several Preventive Medicine Units are available on request to all activities within the major commands to which they are assigned. Some of the laboratories maintained by the Bureau of Yards and Docks for the control of filter-plant operation are equipped for bacteriological analysis. In the absence of conveniently located naval water laboratories, advantage should be taken of the bacteriological facilities of naval hospitals or adjacent Federal or State Health Department laboratories. When chemical laboratory facilities are not locally available, information concerning such analysis may be obtained from the district public works officer.

Section V. DISINFECTION OF MAINS, TANKS, AND TREATMENT UNITS

5-41. Background

(1) Water mains, wells, pumps, filters, storage tanks, and other units of a water supply system become contaminated during construction and repair by workers, surface contamination, and small animals. Flushing the system to remove dirt, waste, and the surface water which is introduced is the first step, but is not sufficient safeguard. To ensure a safe water supply, each unit of the system must be thoroughly disinfected before it is placed in operation.

5-42. Disinfecting Agents

(1) The chemicals used in disinfecting a water system are the same as those used in disinfecting the water, but the strength and contact time are much different. Free chlorine, purchased in the form of a gas, a compound, or a solution, is the only satisfactory chemical for disinfection of waterworks. Grade A hypochlorite (HTH or Perchloron ®) is the most satisfactory as well as the most readily available form for general use. It dissolves easily and contains to 70 percent available free chlorine. One pound in 800 gallons or in 100 cubic feet of water gives a chlorine dose of about 100 p. p. m. Calcium hypochlorite (chloride of lime) is less easily used and contains only about one half as much available chlorine per unit weight of compound. Commercially prepared sodium hypochlorite solutions (Clorox, Zonite, etc.) may be obtained in 5- and 10-percent solution strengths. One gallon of 10-percent solution added to each 1,000 gallons of water will give about 100 p. p. m. free chlorine. All hypochlorites raise the pH of water, thereby reducing the effectiveness of the chlorine. This may be of considerable importance if chlorination raises the pH of the water above a value of 8. For further information on the effect of pH on the disinfecting power of chlorine, refer to figures 5-1, 5-2, and 5-3, and article 5-59. If chlorine gas is used to disinfect mains or equipment, a chlorine-feeding device in the hands of a competent operator is required.

5-43. Dosage Requirements

(1) Chlorine dosage required to disinfect any unit thoroughly depends on the contact time, and the amount of jute, untarred hemp, and organic chlorine-consuming material present. The volume of water in the unit to be disinfected must be computed before chlorine dosage can be estimated. Volumes of water contained in different sizes of pipe are listed below:

Pipe diameter (inches)	Gallons per foot of pipe
2	0.16
2½	0.25
3	0.38
3½	0.51
4	0.66
5	1.04
6	1.50
8	2.61
10	4.08
12	5.88
14	10.45
16	16.32

One cubic foot of water = 7.48 U. S. gallons
One U. S. gallon = 3,785 ml.
See reference 4.

(2) In the transfer from raw to potable water, the system is thoroughly flushed with water to remove any sediment that may have collected. After the flushing, the system is filled with a disinfecting mixture of calcium hypochlorite and treated water. This mixture should consist of not less than 1.2 pounds of high-test calcium hypochlorite, or approximately three times as much chlorinated lime, to each 1,000 gallons of water in order to provide not less than 100 p. p. m. of available chlorine. The high-test calcium hypochlorite should contain not less than 70 percent available chlorine. If the system includes a tank or standpipe, a preliminary mixture of calcium hypochlorite and treated water is prepared in a suitable container. If chlorinated lime is used, the mixture is allowed to stand for about 4 hours before the decanting. The decanted or supernatant chlorine solution is then delivered to the tank or standpipe, along with enough treated water to make a mixture containing not less than 100 p. p. m. of available chlorine. This process is repeated until the tank or standpipe and the entire system are filled. If no tank or standpipe is included, the mixture of not less than 1.2 pounds of

high-test calcium hypochlorite or the larger equivalent amount of chlorinated lime (for each 1,000 gallons of water) is prepared in a suitable container.

The solution is injected directly into the system, and the process is repeated until the system is filled. The disinfectant is retained in the system (and tank or standpipe, if included) for not less than 48 hours and then drained and examined for residual chlorine. If no residual chlorine is present, the process is repeated. After this, the system is flushed with the treated water to be used and may then be placed in service.

5–44. New Facilities

(1) The system is disinfected as in the preceding paragraph. The disinfectant mixture should consist of not less than 0.6 pounds of high-test calcium hypochlorite, or an equivalent amount of chlorinated lime (about 2 pounds), to each 1,000 gallons of water, which provides not less than 50 p. p. m. of available chlorine. The mixture is injected into the system and retained there for not less than 12 hours. The system is then drained, flushed with treated water, and placed in service.

5–45. Repaired or Accidentally Polluted Facilities

(1) The part of the system affected by maintenance, repair, or alteration, or by pollution from impure water, is disinfected as in article 5–43 (2) of this section.

5–46. Large Tanks or Reservoirs

(1) It may be impracticable to disinfect large reservoirs or tanks by the method outlined in article 5–43 (2). In such cases, the reservoirs or tanks are washed down with a strong hose stream of treated water and disinfected by the swabbing or the spraying of all internal surfaces with a solution containing at least 200 p. p. m. of available chlorine. This chlorine solution is flushed to waste after at least 1 hour of retention.

5–47. Disinfection of Wells

(1) Wells should be disinfected after construction, cleaning, or the removal of equipment for repair. When the well equipment is ready for operation, the well should be flushed by pumping to waste until the water is free of turbidity. A dug well may then be disinfected by pouring in the calculated amount of chemical either in powdered form or as a concentrated solution. Water in the well should be agitated to distribute the chlorine. To overcome the

difficulty of mixing the chemical with the water in a drilled well, a volume of 100 p. p. m. solution about 50 percent greater than the quantity of water standing in the hole should be made up in tanks and run down between the riser pipe and the casing.

5–48. Precautions

(1) *Fire protection.*—Adequate fire protection measures must be taken during disinfection of part or all of a water system. If protection is seriously reduced, or if the mission of the activity requires that the water system be out of service for a period shorter than that which disinfection requires, the public works officer, with the advice of the medical officer, recommends the amount of high-test calcium hypochlorite or chlorinated lime required per 1,000 gallons of water to do the job more quickly.

(2) *Bacteriological tests.*—If bacteriological examination of water samples collected after disinfection indicates that the water is not safe, disinfection should be repeated until tests show that water samples from that portion of the system being disinfected are satisfactory. Samples collected immediately after disinfection may not be representative of the water served normally. If bacteriological samples are collected immediately after disinfection, it is desirable that the sampling be repeated several days later to check on the delivered water under normal conditions of operation and use. The water from the system should not be used for domestic purposes until the report on the bacteriological examination of water samples indicates that it is safe. If repeated disinfection does not give satisfactory results, all such water used for drinking or cooking purposes must be boiled before use until the recommendation of the public works officer, on the advice of the medical officer, is received.

5–49. Disinfection in Emergencies

(1) Natural contamination of water supplies may increase markedly because of some wartime emergency. In this case, skid-mounted hypochlorinators and trailer-mounted chlorinators should be drawn for emergency operation from the stock of the district commandant. The equipment cannot be expected to make drinking water safe after bombing, sabotage, or biological warfare have rendered it unsusceptible to disinfection by chlorination. The treatment of and protection of water supplies subjected to contamination by atomic, biological, or c h e m i c a l warfare are covered in technical publications.[1-7]

Section VI. WATER PURIFICATION

5-51. General

(1) Water purification consists in removing or destroying enough impurities in water to make it safe and pleasant to drink. The first and most important step in purification is to select the correct treatment processes and then to arrange them in the right order to do the job. This section discusses each treatment process. Greater detail may be obtained from reference 4.

(2) Generally, good results are obtained by the following arrangement of water treatment processes: coagulation, sedimentation, filtration, and disinfection. Specific purification problems often require additional treatment processes or a different arrangement. No one treatment process is a cure-all.

(3) Methods of purifying water that has not been deliberately poisoned are covered in this section.

5-52. Self-Purification

(1) *General.*—Under favorable conditions, a polluted body of surface water is often partially purified by natural agencies. This self-purification, however, cannot be depended upon to effect complete purification (recovery), but it may decrease the load on mechanical purification equipment.

(2) *Streams or rivers.*—Slight pollution may be difficult to detect, but gross pollution is easily seen, and the recovery of the stream is easily traced. Immediately below points of heavy pollution, such as sewer outlets, turbidity may be high, and within a short distance the water sometimes turns black. Odorous sulfur compounds may be formed, and solids settle on the bottom, forming a sludge. Such settled solids and sludge will soon decompose, forming gases such as ammonia, carbon dioxide, and methane or marsh gas. These gases may form so rapidly that the surface continually bubbles. In still waters scum may form. Life in the water is confined to anaerobic bacteria, larvae of certain insects such as mosquitoes, and a few worms. There are no fish; turtles are generally the only form of higher life. The stream becomes clearer as it continues, allowing sunlight to penetrate the water.

Oxygen dissolves from the air at the water's surface, permitting bacteria to start changing organic matter into nitrates, sulfates, and carbonates. These, together with the carbon dioxide produced from decomposition caused by the anaerobic bacteria, are plant foods. With sunlight now penetrating the water and with abundant food, algae flourish and form a green scum over the surface. As soon as algae appear, self-purification proceeds rapidly, as they take in carbon dioxide, use the carbon, and give out oxygen to the water, thus oxidizing the remaining organic matter. As green algae appear, fish requiring little oxygen, such as catfish and carp, are also found; as the dissolved oxygen increases, more types of fish appear. After recovery, fish find the stream highly favorable, as the algae support various aquatic insects and other organisms on which fish feed. The water is clear or turbid, according to the concentration of algae, and may have odor for the same reason. Throughout the stages of recovery or self-purification, disease organisms are greatly reduced in number because of lack of proper feed, unfavorable temperatures, and pH values of the water. However, the water is still dangerous since all disease organisms have not perished.

(3) *Lakes, reservoirs, and ponds.*—Self-purification in lakes, reservoirs, and ponds is brought about by the same agents as in streams and rivers. However, currents are not as strong, and sedimentation is more important. Sedimentation is often so heavy that large deposits of sludge, dead algae, and other vegetation build up on the bottom. In deep lakes and reservoirs, self-purification is aided by seasonal "overturns." This is simply an exchange of bottom water for surface water caused by the change in density of the water which occurs in the spring and fall.

5-53. Sedimentation

(1) *General.*—Plain sedimentation is the natural settling of solids heavier than water without the addition of chemical coagulants. Solids heavier

than water are held in suspension while water is moving, but settle to the bottom in still water. The time required to clarify water by sedimentation depends on the size of the suspended particles. Large particles settle to the bottom in a few minutes, but very small particles, such as clay, may remain in suspension for several days. Plain sedimentation is seldom used alone to purify water, but is used as a preliminary process in preparing water for filtration.

(2) *To reduce turbidity.*—Plain sedimentation tanks or basins are often used to reduce turbidity in water drawn from swift streams, particularly after rainstorms. If the particles causing the turbidity settle rapidly, plain sedimentation may reduce frequent backwashing of filters.

5-54. Coagulation

(1) *General.*—Coagulation is the process of adding a chemical to water to gather the suspended impurities into particles large enough to settle out rapidly. The standard chemicals for coagulation are filter or ammonium alums. They react with the alkaline substances in the water to form an insoluble jellylike substance which attracts the suspended silt and disease organisms to it. Chemically, these substances are aluminum hydroxide. If water does not contain enough alkalinity, it may be necessary to add an alkaline like soda ash to help form jellylike hydroxide.

(2) *Flocculation.*—Ammonium alum and aluminum sulfate are called coagulants. Either of these can be added to the water in tanks, such as 3,000-gallon canvas tanks; or either one may be added continuously to the water by mechanical-feeding devices.

Regardless of the system, the water must be stirred after the chemicals have been added. The jellylike substance first appears as particles so small that the water has a milky appearance. In this form, the insoluble hydroxide will not clarify the water or settle out. It is necessary to continue stirring the water until the very small particles join with others to form large particles. This process is called flocculation, and the large jellylike particles are called "floc." Operators should work to produce a heavy, rapid-settling floc. Note that flocculation is only one step in the process of coagulation, which also includes the adding of chemicals. After flocculation, sedimentation is generally provided to allow the bulk of the floc to settle and thus reduce the load on the filters.

(3) *Optimum pH.*—Floc forms fastest and is heaviest at one definite pH value, called the "optimum pH." Because this optimum value varies with changes in the impurities in water, it is necessary to determine it by the jar test described in paragraph (4). Optimum pH values generally fall between 4.5 and 7.5, depending on the impurities in the water. Colored water containing only a small amount of

dissolved minerals generally flocculates best between pH values of 4.5 and 6.0, while turbid water with considerable natural alkalinity flocculates best at pH values between 6.0 and 8.0 These values are only indications, as there is only one optimum pH for any given water. Optimum pH varies with rainfall, seasonal changes, etc.

(4) *Jar test for flocculation.*—The correct dose of chemical to use for the treatment of any water at any time can be determined only by trial and error. In a series of jars, beakers, or bottles, portions of raw water are treated with various doses of coagulant, and after thorough mixing, the size and rate of settling of the floc and the clarity of the water are observed. The smallest chemical dose that produces a good floc and complete clarification is the correct one to use in the plant. A mixing device for use in making jar tests is illustrated in figure 5-4.
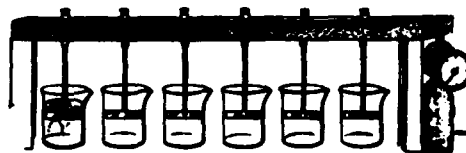
Figure 5-4.—Multiple mixing device.

(5) *Color removal.*—Generally color can be removed in floc when coagulating on the acid side of the pH scale. When alum is used, the water should usually be coagulated at a pH of 4.4 to 6.0. If the pH value is increased later, the color may reappear to a certain extent. Adding soda ash during coagulation may fix the color and prevent removal. Activated carbon may be used to remove color.

(6) *Mixing coagulants.*—To obtain satisfactory coagulation, coagulating chemicals must be thoroughly mixed with the water. In units using feed devices, this is done by adding the chemicals on the suction side of the pump so that the pump impeller mixes them thoroughly. When coagulants are added by the basket method in batch treatment, excellent mixing can be obtained by hanging the basket along the wall of a tank and filling the tank at high rates so that it fills in about 15 minutes. Inlet hoses should be directed along one side of the tank, so that a rapid swirling motion is set up throughout the tank.

This distributes the chemicals throughout the water effectively.

(7) *Accelerating flocculation.*—To obtain best flocculation in the minimum time, the rate of floc formation should be accelerated by agitating the water. This is done best by "tapered" mixing, the water being agitated vigorously while the chemicals are being added and then more and more slowly over a period of about 30 minutes. When coagulants are added to water as it enters a sand filter, the flocculation period is brief, and agitation is not con-

tinuously controlled. For waters that do not floccu-late readily, this process does not assure reliable clarification by the filter (art. 5-57), and complete pretreatment should be used.

5-55. Chemicals Used in Coagulation

(1) The chemicals commonly used in coagulation are discussed below. Alum coagulants are generally used with military purification equipment.

(2) *Alum coagulants*

(a) *Alum.*—Filter alum or aluminum sulfate is available either in lump, granular, or powdered form. It is an acid salt and hence is corrosive to most metals. It is readily soluble in water and is easily applied in solution or dry.

(b) *Black alum.*—Black alum is filter alum which contains 2 to 5 percent by weight of powdered activated carbon.

(c) *Ammonium alum.*—Ammonium alum is used in mobile and portable purification units and should not be confused with filter alum. Use of ammonium alum facilitates controlled application of coagulant over a period of time because it is less soluble than filter alum and therefore dissolves more slowly in alum pots and chemical baskets. It does not dissolve readily in cold waters. Alum pots are not accurate feeding devices, even with ammonium alum, but are more compact than other feeds.

(d) *Sodium aluminate.*—Sodium aluminate is a coagulant used with alum for special treatment processes such as water softening and color removal.

(3) *Ferric coagulants*

(a) *Copperas.*—Ferrous sulfate, commonly known as copperas, is a granular acidic salt used with lime for coagulation. Lime must be added because the alkalinity and pH value of natural water are generally too low to react with copperas to form the desired ferric hydroxide floc.

(b) *Chlorinated copperas.*—The oxidation of copperas by the dissolved oxygen of water occurs only at pH values above about 8.5. However, chlorine may be used to react with copperas irrespective of the pH value of the water. From this reaction, ferric sulfate and ferric chloride are formed and in turn act as coagulants.

(c) *Ferric sulfate.*—Ferric sulfate is a dry commercial coagulant.

(d) *Ferric chloride.*—Three commercial forms of ferric chloride are available: liquid, crystalline, and anhydrous material.

(e) *Summary of ferric coagulants.*—Chlorinated copperas, ferric chloride, or ferric sulfate may be used in place of alum coagulants. Ferric coagulants are very corrosive and require corrosion-resistant facilities. There are a number of practical differences between alum and ferric coagulants, however, which should be noted. Briefly, these differences are as follows:

(1) Ferric hydroxide is formed at low pH values, and consequently coagulation with ferric coagulants at pH values as low at 4.5 is possible.

(2) Ferric hydroxide is insoluble over a wider range of pH values than aluminum hydroxide.

(3) Ferric hydroxide does not redissolve at high pH values.

(4) *Special coagulation aids*

(a) *Artificial turbidity.*—Under certain conditions, materials such as bentonite, Fuller's earth, or local clays may be added to the water to create an artificial turbidity which increases the rate of floc formation and settlement.

(b) *Sulfuric acid.*—Sulfuric acid is occasionally used with alum as an aid in coagulating colored water. As this acid causes severe burns when in contact with skin or clothes, special safety precautions must be observed when it is used.

5-56. Chemicals to Adjust pH

(1) The chemicals commonly used to adjust pH values as an aid in coagulation are discussed below.

(a) *Soda ash.*—Soda ash (sodium carbonate) is highly soluble in water. It is used when waters do not contain enough natural alkalinity to react with the coagulant. The soda ash supplied for field use comes in briquettes which dissolve more slowly than ammonium alum. Soda ash should be procured by specification to contain at least 98 percent sodium carbonate, because this quality is assumed in the calculation of the chemical dose.

(b) *Lime.*—Quick lime (calcium oxide) or slaked lime (calcium hydroxide) may be used to provide artificial alkalinity. They are also used in water softening.

5-57. Filtration

(1) *General.*—When water filters through sand, the following changes occur:

(a) Suspended and colloidal matter is partially removed.

(b) Chemical characteristics of the water are changed.

(c) Quantity of bacteria is materially reduced.

(2) Obviously, particles of suspended matter too large to pass through the interstices of sand grains are filtered out by mechanical straining. Colloidal matter, however, or bacteria too small to be strained out are not removed by this process but by sedimentation and adsorption. Voids between the grains act as minute sedimentation basins in which fine suspended particles settle on the sand grains. The action is aided by a gelatinous coating formed on the surface of the sand grains by previously deposited bacteria and colloids. Because living organisms exist in filters and matter is used in the metabolism of all organisms, the chemical makeup of matter on the filter is changed in some degree by the growth of the organisms on the bed.

(3) Most benefits derived from filtration are not caused by action occurring at points generally distributed throughout the sand bed, but from action occurring at the surface of the sand in the layer of deposited matter and after the filtration process has been operating for a period of time. The layer contains a jellylike substance in which biological activities are at their highest. It is called the "schmutzdecke" (literally "dirty skin"), and operation of the plant depends on it. When the filter has been in use for some time, the pressure necessary to force water through the schmutzdecke and the sand increases. As a certain point of pressure is reached, it becomes necessary to clean or backwash the filter.

(4) In treatment of water, two general types of filters are used—slow sand and rapid sand. The former is seldom built today.

(5) *Slow-sand filters.*—Slow-sand filters contain fine-grain sand and have low-filtration rates. They are usually used when coagulation is not included in the treatment process.

The use of slow-sand filters has been practically discontinued because of their high cost per unit of capacity and the labor required to clean them. Generally, slow-sand filters have little military value because they require fixed installations with very large filter areas, clear or easily clarified sources, and experienced designers. In areas where

water sources are contaminated with amebic cysts and where it is difficult to obtain diatomite filters, slow-sand filters have the following advantages for permanent or semipermanent stations: They can be built of local materials; they require a minimum of mechanical equipment; and they can be operated with native labor.

(6) *Rapid-sand filters.*—Rapid-sand filters operate either by gravity or pressure principles.

(a) *Gravity filters.*—Gravity filters (fig. 5–5) are essentially open-top rectangular concrete boxes, about 10 feet deep. An underdrain system at the bottom supports the layer of gravel, which in turn supports the layer of filter medium. The total head in a gravity filter equals the positive head of water above the underdrain plus the negative head from the underdrain to the water in the clear well. Gravity filters are usually designed to filter about 2 gallons per minute (g. p. m.) per square foot of filter-bed area. However, in emergency, up to 4 g. p. m. per square foot can be obtained if prior treatment by flocculation and sedimentation produces very low turbidity.

(b) *Pressure filters.*—In pressure filters (fig. 5–6), the bed is enclosed in a pressure vessel and water either is pumped into the vessel or is drawn through the filter by a suction pump. Pressure filters are better than gravity filters when small volumes of water are to be filtered, because no other

WASH TROUGHS

FILTER SAND

GRADED GRAVEL

FILTER TANK

PERFORATED LATERALS

CAST-IRON MANIFOLD WITH
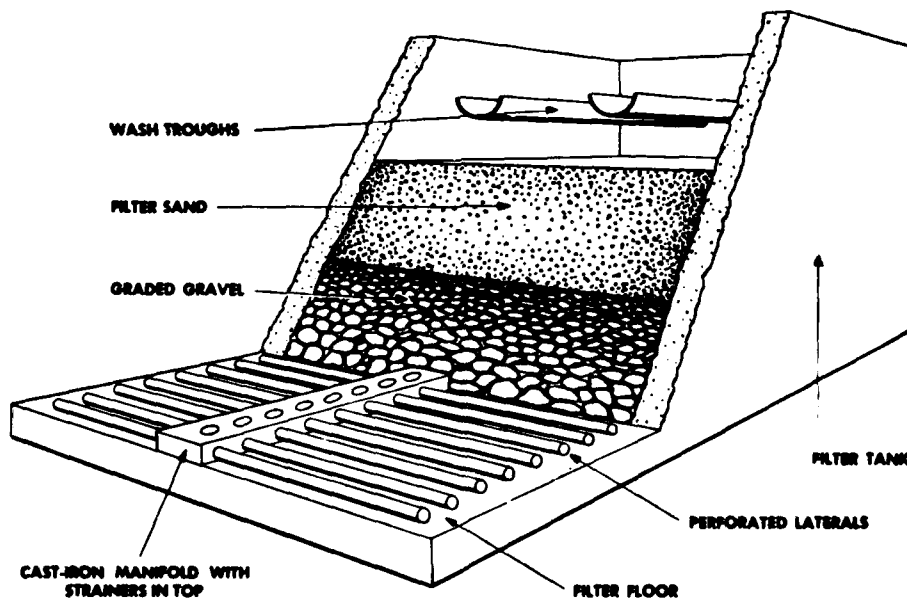STRAINERS IN TOP

FILTER FLOOR

Figure 5–5.—Cutaway view of gravity sand filter showing underdrains and filter bed.
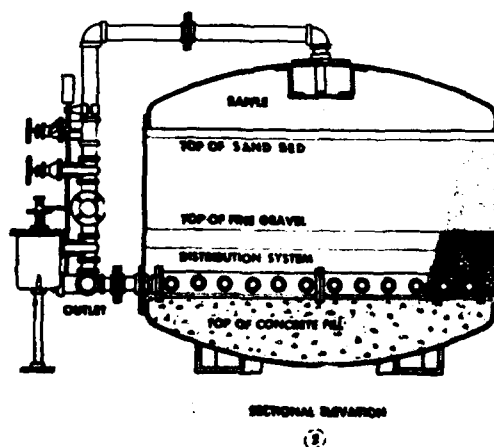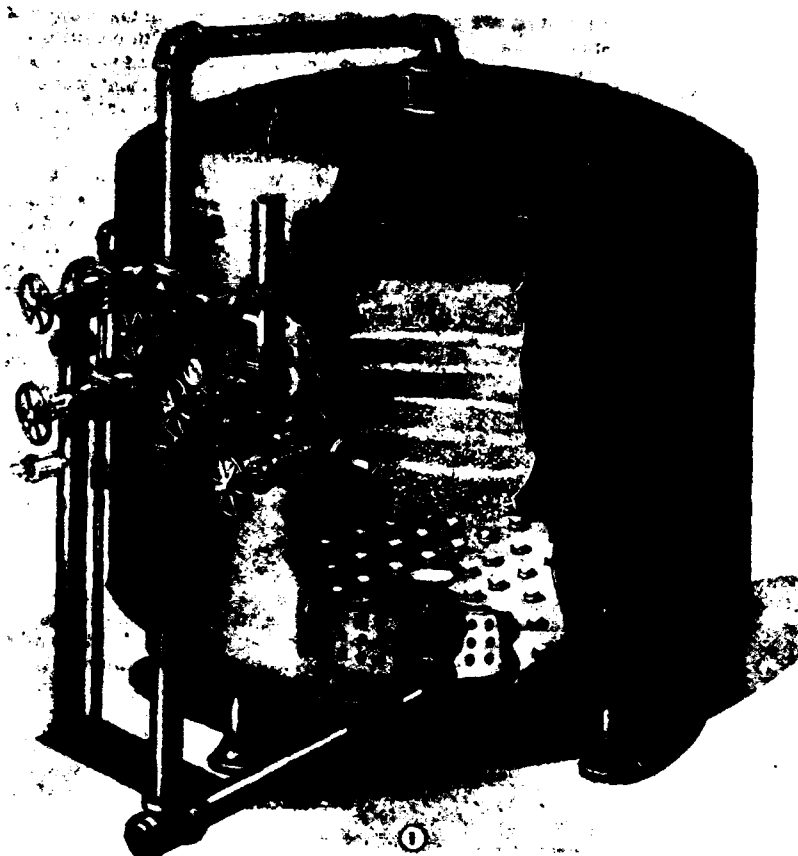
Figure 5-6.—Cross-section of vertical-pressure type water filters.

pumping is needed. Pressure filters are installed either vertically or horizontally. They operate at the same rates as gravity filters. Filter rates employed in the mobile and portable water-purification units are somewhat higher than the usual 2 gallons per square foot.

(c) *General.*—Rapid-sand filters operate effectively at rates at least 50 times as great as those of slow-sand filters. This is possible because they use coagulation to help in producing clear water and they have a backwashing arrangement which quickly removes accumulated solids. Rapid-sand filters function primarily as straining agencies for the flocculated material in water, and benefit from the accumulated gelatinous schmutzdecke collected in the sand. Sudden changes in rate of flow must be avoided to prevent dislodging this accumulated material. The portable sand-filter units can be operated to remove amebic cysts and to produce filtered water of generally high quality by special measures of control but are not as effective as diatomite filter units.

(7) *Diatomite filtration.*—Diatomite filtration is the process of removing suspended matter from water by passing it through a layer of diatomaceous silica. Diatomite filtration of pretreated water consistently produces a filtrate of less than 0.1 p. p. m. turbidity, completely removes chlorine-resistant organisms such as amebic cysts and cercariae of schistosomes, and removes more than 90 percent of all bacteria.

(a) Special types of diatomite filters have been developed for use in mobile installations. These filters (fig. 5-7) are included in sets of equipment containing pumps, tanks, and supplies that provide for pretreatment, chlorination, filtering, water storage, and water distribution.

(b) To prevent rapid clogging of the original layer of diatomite filteraid by foreign matter in the water, the units are equipped with feeding devices which continuously supply fresh diatomite filteraid to the influent water. The rigid particles of filteraid mix with the compressible matter in the water to form a porous filter cake. When the resistance of this cake to flow becomes too great, it is removed by backwashing the unit and is replaced by a new filter layer. In the filtering of pretreated water, filtered water quality does not depend on pressure or flow rates. Reduced pumping rates are not required to obtain clear water.

(c) Diatomite, also called "diatomaceous earth," or "filteraid," consists of the skeletal remains of minute algae, called diatoms, found in marine deposits which have been lifted above sea level. Crude diatomite is quarried and processed as diatomaceous-silica filteraid, which is inert to water and to

FILTERED WATER
DISCHARGE HOSE

PRECOAT TANK

PRECOAT SUCTION
HOSE

RAW WATER INLET
HOSE - 1½ INCH

PRESSURE FILTER UNIT

PUMP AND ENGINE SET

PRECOAT DISCHARGE
HOSE

PUMP
DISCHARGE
HOSE-
1½ INCH

WASTE HOSE - 1½ INCH
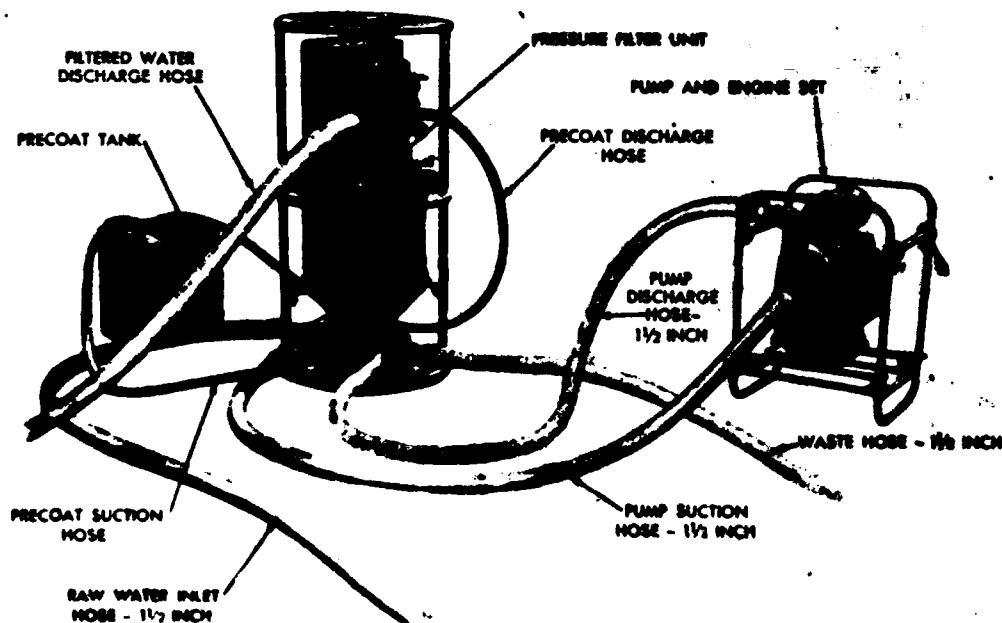
PUMP SUCTION
HOSE - 1½ INCH

Figure 5-7.—Pressure filter unit (diatomite) and one pump and engine set in operating position.

water-treatment chemicals. When used as a filter medium, diatomite requires a rigid supporting base or septum that is porous enough to permit maximum flow without significant loss of head yet fine enough to support the filter cake. For this purpose, cylindrical elements of helically wound wire, porous plastic, porous rubber, or porous refractory minerals (fig. 5-8) are most satisfactory.
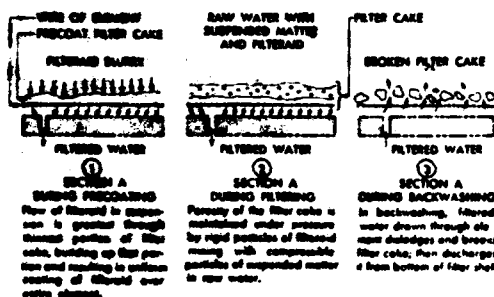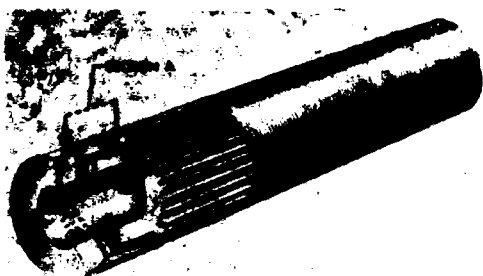
(d) A precoat layer of filteraid is deposited on the cylinder by circulating diatomaceous slurry through the unit. An almost uniform coating is formed over the entire septum, because flow is greatest through the thinnest portion of the coating. IF FLOW IS STOPPED DURING A FILTER RUN, THE FILTER MUST BE BACKWASHED AND A NEW PRECOAT APPLIED.

(e) During the filter cycle (fig. 5-9), the porosity of the filter cake is maintained by the slurry feeder. Unless filteraid is added, compressible particles in the raw water form a slime over the surface of the precoat layer, causing filter runs as short as 5 or 10 minutes. By adding filteraid slurry during filtration, the cake surface continually increases and the porosity is maintained longer. The quantity of slurry feed required depends on the character and amount of suspended solids in the unfiltered water. With relatively clear raw water or with well-

coagulate and settled water, filter cycles last several hours without continuous slurry feed. The optimum filteraid slurry feed is determined by trial, using varying quantities of filteraid during a series of filter cycles and comparing the results.

(f) Diatomite filters are backwashed by reversing the direction of flow and drawing *filtered* water from the storage tank through the filter. It requires less than 3 percent of the filt "'s output to dislodge and remove the clogged filter cake. Diatomite filters should be backwashed whenever the porosity of the filter cake has decreased to a point at which filter output falls off noticeably.

(g) *Advantages of diatomite filtration.*—The principal advantages of diatomite filtration are the superior and uniform quality of filtered water output.

(8) *Operation of filters*

(a) An influent pipe carries partially clarified water from the sedimentation basin to the filter bed, discharging it behind a baffle wall so that water currents will not disturb the sand bed. The water passes over the baffle, filters through sand and gravel into the underdrains, passes through a ratecontroller, and is then collected in a filtered-water reservoir or clear well.

(b) When a filter bed is first put into operation or has just been washed, water passes through the sand too quickly for efficient filtration. Therefore, the effluent line must be throttled to reduce the rate of flow. As the filter bed becomes clogged, the rate of filtration decreases and the amount of throttling must be reduced accordingly to keep the rate of filtration uniform. Manual control of the filter rate is impracticable, and consequently an automatic device known as the rate-of-flow controller is used. Most rate-of-flow controllers are governed by a venturi in the filter effluent line. Pressure differentials produced by the venturi act on a balanced valve which in turn actuates the controller. It is necessary to measure rate of flow through each filter periodically to check the accuracy of the rate-of-flow controller.

(c) Loss of head is the difference between static level of water above the filter bed and water in the underdrain. During normal filtration, increasing amounts of foreign matter collect in the top few inches of the sand bed. As this collection increases, the passage of water through the filter is slowed. Water pressure below the bed decreases, thus increasing loss of head. The gage which measures loss of head plays an important part in filter operation and a reading that shows a loss of 7 to 9 feet indicates that the filter needs washing. This gage also reveals cracks in the filter-bed surface which allow the water to pass through to the underdrain easily. This is a serious condition, since water which passes through the cracks is not properly filtered.

(d) It is desirable to operate filters at as uniform a rate as possible. Therefore, clear wells are
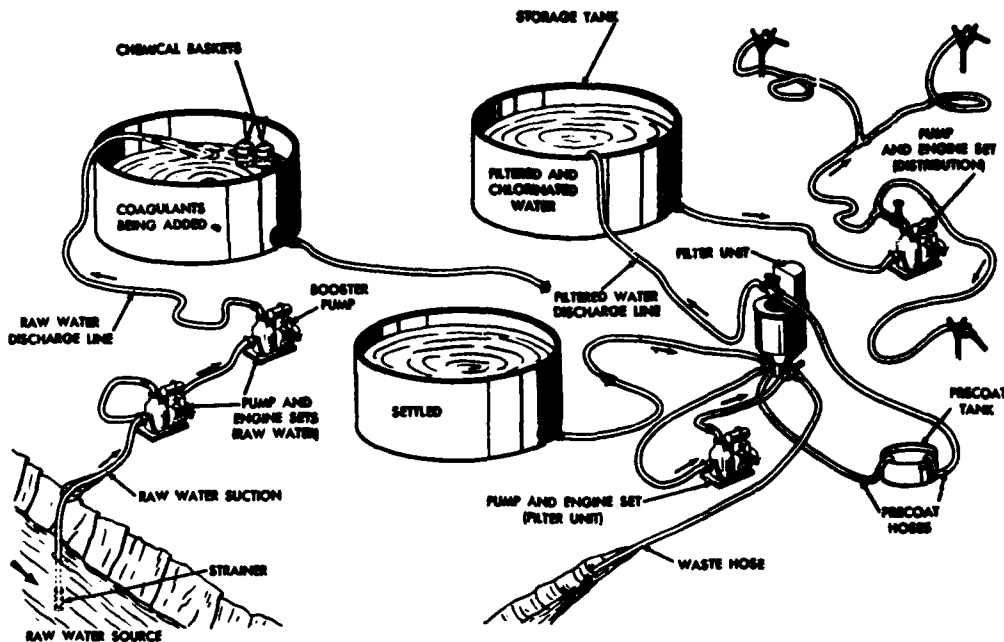
Figure 5-9.—Typical arrangement of diatomite water-purification equipment.

built to provide a reservoir of filtered water to meet fluctuations in demand. They may be supplemented with elevated storage.

(e) A filter bed needs washing when the loss-of-head gage shows a loss of from 7 to 9 feet or after a filtering period or run of 100 hours. The bed is washed by reversing the flow, forcing filtered water up through the gravel and sand. The water loosens the sand bed, agitating the grains, and washing accumulated floc and foreign matter off the grain surfaces. The wash water rises into the wash-water troughs and flows to the drain, carrying the foreign matter with it.

(9) *Operational difficulties*

(a) If a filter bed is not backwashed correctly, sand grains and foreign matter begin to stick together. Over a period of time large clumps, called mud balls, are formed. They lower the efficiency of the filter bed and must be removed. Surface washing usually breaks down these formations and can then be removed by backwashing. It is sometimes necessary to remove mud balls manually with a 10-mesh screen attached to a long handle.

(b) Normally, filter sands become clogged only at the surface and are restored to use by ordinary washing methods. Sometimes, however, the entire sand bed becomes so clogged and caked that it does

not filter properly. It can be restored to use only by removal from the filter and through washing.

(c) Air binding occurs when pockets of air accumulate in the sand. It interferes with proper filtration as indicated by high loss of head.

(d) Micro-organisms frequently accumulate so rapidly on the filter-bed surface that the rate of filtration is reduced as much as 50 percent. When this occurs special pretreatment of the water is always mandatory.

5-58. Storage

(1) Suitable storage facilities may be constructed of concrete, steel, brick, or wood above the land surface or of concrete or brick if partly or wholly below the land surface. Designs for typical manhole covers and piping installations are shown in figure 5-10. Such installations assist in protecting the water supply from possible contamination. Asphalt or tar for waterproofing the interior of storage units is not recommended on account of the objectionable taste imparted to the water and the possibility of undesirable chemical reaction with the materials used for treatment. Specifications covering the painting of water tanks have been prepared by the Bureau of Yards and Docks. The specifications provide proper safeguards concerning the use of lead-base paints.
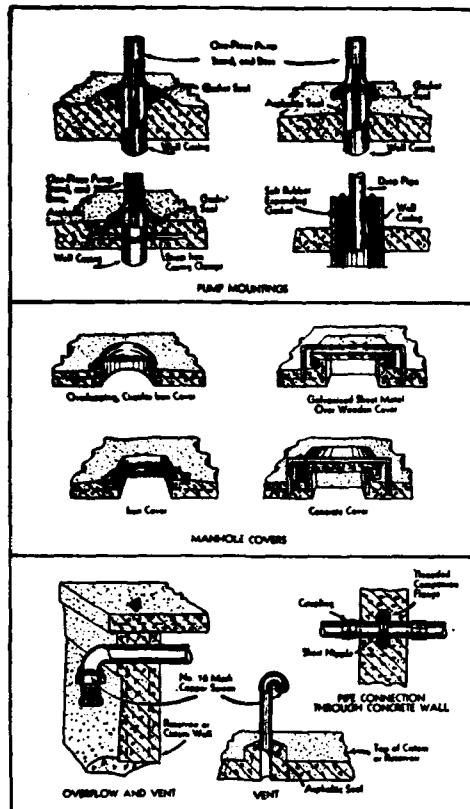
Figure 5-10.—Typical pump mountings, manhole covers, and piping installations.

(2) Surface reservoirs formed by the damming of open streams are not recommended for storage of water for human consumption. They may be used for stock watering, and a fence enclosure is recommended for proper maintenance.

(3) All tanks for storage of water for domestic supply should be completely covered and so constructed as to prevent the possibility of contamination of the tank contents by outside water or other foreign matter. Figure 5-10 shows several designs for manhole covers and piping connections to prevent the entrance of contaminating materials and surface drainage. Concrete and brick tanks should be made watertight by a lining of rich cement mortar. Wood tanks, generally of redwood or cypress, require no special consideration beyond the requirement for the covering and the screening of openings against mosquitoes, flies, and other small insects.

(4) Tanks for stock water should be properly constructed and partially covered to prevent cattle from getting into the tank, and the area around the tank should be sloped to drain away from the tank.

(5) Steel pressure tanks of relatively small capacity are widely used in connection with automatic systems for individual homes. The types available are of standard construction and present no sanitation hazards. The capacity of storage tanks, other than hydropneumatic tanks, in connection with a pumped supply should be not less than 2 days' requirement and should be correspondingly greater where special conditions indicate the need. Special care should be taken not to make storage tanks, cistern, or pipelines unsafe by bringing in an emergency water supply that has been contaminated at its source or in transit.

(6) A typical concrete reservoir with screened inlet and outlet pipes is shown in figure 5-11. This figure also illustrates the sanitary manhole cover which overlaps an elevated rim and prevents any drainage from entering the reservoir in the event it is constructed where one side is at ground elevation. This type of manhole frame and cover is generally designed so that it may be locked to prevent access by unauthorized persons.
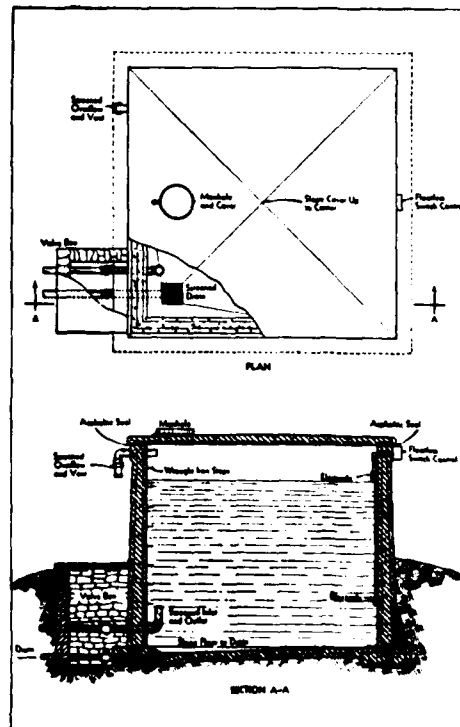
Figure 5-11.—Typical concrete reservoir.

5-59. Disinfection of Water Supplies

(1) Water is most commonly treated with chlorine gas or compounds, or iodine (the latter provided for small-volume purification in the field). Other methods should not be used, except in emergency, without a careful review of the literature to determine their current state of development. The terms chlorination and disinfection are here used to indicate the same process.

(2) Chlorination includes all processes using chlorine gas or chlorine compounds to produce in the water either of two distinctly different disinfecting agents, free chlorine or chloramines. Which of these predominates depends on the ratio of chlorine dose to the ammonia-nitrogen (ammonia radical expressed as nitrogen). Ammonia may be a natural constituent of the water or may be added. If the chlorine: ammonia-nitrogen ratio is below 5:1, chlorine reacts to form chloramine. Chloramines are destroyed by further increases in the chlorine dose until, at a chlorine: ammonia-nitrogen ratio of about 9:1, the chloramine has been completely oxidized. This point of minimum residual is called the breakpoint. Chlorine added beyond this point produces free-chlorine residuals.

(3) Five methods of chlorine dose control are in use:

   (a) Fixed dose,

   (b) Minimum residual after fixed contact time,

   (c) Minimum residual throughout distribution system,

   (d) Superchlorination-dechlorination and,

   (e) Breakpoint chlorination.—For purposes of illustration, figure 5-12 shows an ideal diagrammatic residual-chlorine curve in the presence of 0.9 p. p. m. of ammonia-nitrogen. With 0.9 p. p. m. of ammonia-nitrogen initially present, there is no change in the ammonia-nitrogen content until 4.5 p. p. m. of chlorine has been added (the ratio of chlorine to ammonia-nitrogen is approximately 5:1). Until the combined available-chlorine residual is at the maximum point (popularly called the "hump") the orthotolidine chlorine-residual content is the same as the amount of chlorine added, and all of the residual chlorine is present as combined available chlorine. After the "hump" has been reached, added amounts of chlorine result in corresponding decreases in orthotolidine residual chlorine and ammonia-nitrogen, until, when about 9.0 p. p. m. has been added, the chlorine-residual content and the ammonia-nitrogen content will be zero. Within this part of the curve the residual chlorine present is combined available chlorine. Increments beyond this "breakpoint" (zero point) produce corresponding increases in residual chlorine, and this residual chlorine is "free" available chlorine.

(4) Free chlorine appears to be about 30 times more effective than chloramines in bactericidal action if the pH is around 7.0 or lower. At high pH, it
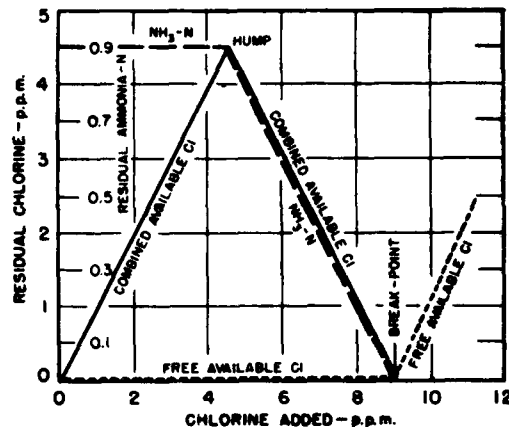
Figure 5-12.—Ideal residual-chlorine curve (ammonia solution).

is not. It is, therefore, necessary to distinguish between free chlorine residuals and chloramine residuals. The orthotolidine test as ordinarily used does not do this. However, by reading the flash color, i. e., the color appearing at 10 seconds after addition of the orthotolidine, an idea of the free chlorine content of the sample may be obtained. The color after 5 minutes measures the sum of free chlorine, chloramine, and interfering substances. Temperature of the sample should be below 60° F.

(5) The pH value of water has a marked effect on the bactericidal action of both free chlorine and chloramines. Their effectiveness decreases so rapidly with increasing pH that under some conditions it may be better to lower the pH than to add the excessive dose of chlorine required at high pH values. The latter has been considered, though not adopted, in connection with superchlorination using hypochlorites. Large doses of hypochlorites materially increase the pH value.

5-60. Control of Chlorination

(1) The following rules are suggested as safe guides in the control of chlorine dosage:

   (a) Apply chlorine continuously at a point where thorough and rapid mixing with the treated water will be effected; or, in batch chlorination, mix by thorough stirring.

   (b) Differentiate free chlorine and chloramine residuals.

   (c) If the residual is free chlorine and the pH is below 7, chlorinate to obtain 0.2 p. p. m. free chlorine residual after 20 minutes' contact. Increase this residual 0.1 p. p. m. for each increasing pH interval above 7, i. e., for pH 7 to 8 maintain 0.3 p. p. m., and for pH 8 to 9 use 0.4 p. p. m. residual, keeping the pH below 9.

(d) It is recommended that in common circumstances chlorination be accomplished to levels of free-residual chlorine only. Both the production and the testing of free chlorine in the hands of untrained or partially trained personnel is more practical and more reliable than the use of an evaluation of chloramine residuals (combined chlorine). Where it is necessary to use breakpoint chlorination, the addition of chlorine in sufficient amounts to produce the desired level of free available chlorine in most cases automatically carries the operator through the procedure of breakpoint chlorination. Under certain conditions, the use of chloramine (combined chlorine) is a desirable method, but should be performed or supervised by adequately trained personnel. Further details may be found in reference 4.

(2) Where bacteriological tests indicate that the above-minimum requirements are inadequate a residual of free chlorine of from 0.1 to 0.2 p. p. m. may be maintained throughout the distribution system, in which case chlorination at the plant is regulated to provide the desired residual at distant points in the distribution system. In no case should the maintenance of residuals in the distribution system be looked upon as a satisfactory substitute for proper sanitary protection of the water during distribution (art. 5-6 (5)).

(3) Treatment by coagulation, sedimentation, and filtration, followed by chlorination, probably provides adequate protection against the cysts of *Endamoeba histolytica*. (See art. 5-6 and 5-14.)

(4) Municipal-type water treatment including coagulation, filtration, and chlorination provides adequate protection against the cercariae of schistosomiasis. HTH in doses sufficient to produce one part per million free available chlorine residuals after 30 minutes' contact time has been shown to destroy the infectious organism. In filtered or naturally clear water one iodine tablet in a canteen of water has been shown to produce complete protection after 5 minutes' contact time. In the presence of high organic content, however, even two tablets of iodine per canteen after 30 minutes' contact time may prove insufficient to kill all the cercariae. Under these circumstances, highly turbid waters must either be filtered and clarified or be allowed to stand for 48 hours prior to use inasmuch as the cercariae die a natural death in that period of time.

5-61. Chlorination Equipment

(1) Chlorination equipment at Navy installations is selected, installed and operated by the Public Works Department under the management control of the Chief of the Bureau of Yards and Docks. At Marine Corps managed installations this work is the responsibility of the maintenance officer or public

works officer under the management control of the Commandant of the Marine Corps. The following information has been extracted from reference 4. For more detailed information on this subject, refer to this publication.

(a) Chlorination equipment should have a minimum capacity at least 50 percent greater than the highest expected rate of feed.

(b) Automatic proportioning of rate of chlorine feed to rate of water treated should be provided at all plants where the flow varies more than 50 percent from the average. Manual control should be permissible only where the rate of flow is relatively constant and an attendant is always at hand to effect promptly any necessary adjustments in dosage.

(c) All chlorination equipment should be installed in duplicate to ensure uninterrupted operation. Duplicate units should be operated frequently to assure workability. A complete stock of spare parts and tools should be maintained for emergency replacements and repairs.

(d) Chlorination equipment should be capable of satisfactory operation under every condition at the plant. A supply of water, free of coarse suspended matter, should be available under adequate pressure to ensure the continuous operation of solution-feed chlorinators. Alternative sources of power for maintaining this pressure should be provided where necessary to ensure continuous operation.

(e) Scales, preferably of the recording type, should be provided for weighing cylinders of chlorine in order to obtain loss-of-weight figures for checking the rate of feed setting on the chlorinators.

(f) A sufficient number of cylinders of chlorine should be connected to chlorinators in use to assure adequate operating pressures at all times.

(g) A sufficient stock of chlorine gas or chlorine compounds should be on hand to preclude any danger of exhausting the supply of chlorine.

(h) Hypochlorite solutions should be prepared in a separate mixing tank and then diluted and allowed to settle so that only clear liquid is withdrawn to the solution storage tank which supplies the chlorinator.

(i) The strength of hypochlorite solutions should be checked frequently and should be renewed as frequently as necessary to maintain them at satisfactory strength for accurate control of chlorination.

(j) Chlorinators for feeding gas, and cylinders of chlorine should be housed above ground in special rooms, provided with exhaust fans that can be set in operation from outside the room and provided with heating and, if necessary, cooling facilities to maintain temperature above 60° F., but below maximum outside summer temperatures. Heat shall never be applied directly to chlorine cylinders.

(k) Suitable gas masks and a bottle of ammonia for testing for leaks should be kept immediately outside of rooms in which chlorine gas is stored or used.

5-62. Operation and Laboratory Control

(1) Every water purification and disinfection plant should be under the charge of a technically trained supervisor. Plants treating variable or highly polluted raw waters should have continuous and full-time trained supervision. Under some conditions small plants may be left in the hands of attendants or operators who lack scientific training but who have been instructed in the mechanical operation of equipment. In such plants the supervisor should be in constant touch with plant attendants. He should be on call in any emergency and should visit the plant as often as is necessary to assure the safety of the water.

(2) For the ordinary filter plant, the minimum schedule of laboratory tests should include determinations of turbidity, color, alkalinity, pH, hardness, bacterial counts, coliform bacterial numbers, residual chlorine and, where coagulation is used, jar tests to control the dosage of coagulants. The frequency of testing required for proper operation control of a filter plant depends on the character of the water treated and on its variability. Bacterial counts and coliform tests on the raw and finished water should be made daily. Turbidity and chlorine residuals in the finished water should be determined hourly.

5-63. Judging the Efficiency of Operation

(1) In judging the efficiency of operation of a water plant the following important items should receive consideration:

(a) Training and experience of supervisor and operating staff.

(b) Adequacy of operation records.

(c) Efficiency of laboratory control.

(d) Suitability of plant design to the character and pollution of the raw water.

(e) Capacity of plant in relation to the average and maximum output required.

(f) Freedom of plant from sanitary defects.

REFERENCES

1. *Water Supply for Advanced Bases.* BuDocks Publications TP-PL-6.

2. *Low Temperature Sanitation and Cold Weather Medicine.* NAVMED P-5053. By Technical Assistant to Chief of Naval Operations for Polar Projects.

3. *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes, current edition.* Prepared and published jointly by American Public Health Association, American Water Works Association, and Federation of Sewage and Industrial Wastes Association. New York, N.Y.

4. *Operation and Maintenance of Water Supply Systems,* NAVDOCKS MO-210 (Interim Issue), November 1962.

5. *ABC Warfare Defense Ashore.* NAVDOCKS TP-PL-2.

6. *Radioactivity in Water Supply and Waste Water Systems; Peacetime Detection and Control.* NAVDOCKS MO-218.

APPENDIX A*

BACKGROUND USED IN DEVELOPING THE 1962 DRINKING WATER STANDARDS

The Public Health Service Drinking Water Standards of 1962 have been predicated upon the best and latest information available at the time of their promulgation. The concepts and rationale included in this Appendix were used in making this revision and should enable those whose responsibility it is to interpret, apply, or enforce the Standards to do so with understanding, judgment, and discretion.

- A—Source and Protection
- B—Microbiology
- C—Physical Characteristics
- D—Chemical Characteristics
- E—Radioactivity

A—SOURCE AND PROTECTION OF SUPPLY

Mounting pollution problems indicate the need for increased attention to the quality of source waters. Abatement and control of pollution of sources will significantly aid in producing drinking water which will be in full compliance with the provisions of these Standards and will be esthetically acceptable to the consumer.

Production of water supplies which poses no threat to the consumer's health depends upon continuous protection. Because of human frailties associated with this protection, priority should be given to selection of the purest source. Polluted sources should be used only when other sources are economically unavailable and then only when the provision of personnel, equipment, and operating procedures can be depended upon to purify and otherwise protect the drinking water supply continuously.

Well waters obtained from aquifers beneath impervious strata, and not connected with fragmented or cavernous rock, are usually considered sufficiently protected to preclude need for purification. However, ground waters are becoming polluted with increasing frequency and the resulting hazards require special surveillance. An illustration of such pollution is the presence of chemical pollutants originating either from sewage or industrial effluents. Surveillance of the safety of these water supplies should include chemical, physical, radiological, and biological examination.

Surface waters are subjected to increasing pollution and although some surface waters may be sufficiently protected to warrant their use as a supply without coagulation and filtration, they are becoming rare. Surface waters should never be used without being disinfected. Because of the increasing hazards of pollution, the use of surface waters without coagulation and filtration must be accompanied by intensive surveillance of the quality of the raw water and the disinfected supply in order to assure constant protection. This surveillance should include sanitary survey of the source and water handling, as well as biological, radiological, physical, and chemical examination of the supply.

The degree of treatment should be determined by the health hazards involved and the quality of the raw water. During times of unavoidable and excessive pollution of a source already in use, it may become necessary to provide extraordinary treatment (e.g., exceptionally strong disinfection,[1] improved coagulation, or special operation). If the pollution cannot be removed satisfactorily by treatment, use of the source should be discontinued until the pollution has been reduced or eliminated. When used, the source should be under continuous surveillance to assure adequacy of treatment in meeting the hazards of changing pollution conditions.

The adequacy of treatment should be judged, in part, upon a record of the quality of water produced by the treatment plant and the relation of this quality to the requirements of these Standards. Evaluation of adequacy of protection by treatment should also include frequent inspection of treatment works and their operation. Conscientious operation by well-trained, skillful, and competent operators is an essential part of protection by treatment. Oper-

[1] See reference to relationship of chlorine residual and contact time required to kill viruses, in section on Microbiology.

ator competency is encouraged by a formal program leading to operator certification or licensing.

Delivery of a safe water supply depends upon the protection of the water in the distribution system as well as protection of the source and by treatment. Minimum protection in the distribution system should include programs which result in the *provision* of sufficient and safe materials and equipment to treat and distribute the water; *disinfection* of water mains, storage facilities, and other equipment after each installation, repair, or other modification which may have subjected them to possible contamination; *prevention* of health hazards, such as cross-connections or loss of pressure because of over-draft in excess of the system's capacity; and *routine analysis* of water samples and frequent survey of the water supply system to evaluate the adequacy of protection. The fact that the minimum number of samples are taken and analyzed and found to comply with specific quality requirements of these Standards is not sufficient evidence that protection has been adequate. The protection procedures and physical facilities must be reviewed along with the results of water quality analyses to evaluate the adequacy of the supply's protection. Knowledge of physical defects or of the existence of other health hazards in the water supply system is evidence of a deficiency in protection of the water supply. Even though water quality analyses have indicated that the quality requirements have been met, the deficiencies must be corrected before the supply can be considered safe.

B—MICROBIOLOGY

BACTERIOLOGICAL QUALITY

The bacteriological requirements for drinking water as specified by the 1946 Drinking Water Standards have been discussed extensively.

Coliform Group

Of the two bacteriological examinations—(a) agar plate count for 24 hours at 35° C, and (b) quantitative estimation of the coliform group which have come to be recognized generally—the test for organisms of the coliform group is almost universally conceded to be the most significant. The plate count at 35° C or (20° C) incubation temperature is not required in the definition of a safe standard for potable waters but is useful as a routine quality control test in the various water treatment procedures and as a method for estimating the sanitary conditions of basins, filters, etc.

It does not seem advisable to repeat extensive discussions of the principles involved in the quantitative interpretation of fermentation tests according to the "most probable number" concept in multiple portions of equal volume and in portions constituting a geometric series.

COLIFORM GROUP AND FECAL COLIFORM ORGANISMS AS INDICATORS OF POLLUTION IN DRINKING WATER [1]

The coliform group, as specified in U.S. Public Health Service Drinking Water Standards is defined in *Standard Methods:* "The coliform group includes all of the aerobic and facultative anerobic, Gram-negative, nonspore-forming, rod-shaped bacilli' which ferment lactose with gas formation within 48 hours at 35° C."

The coliform group includes organisms that differ in biochemical and serologic characteristics and in their natural sources and habitats. *Escherichia coli* is characteristically an inhabitant of human and animal intestines. *Aerobacter aerogenes* and *Aerobacter cloacae* are frequently found on various types of vegetation and in materials used in joints and valves of pumps and in pipelines. The intermediate-aerogenes-cloacae (I.A.C.) subgroups may be found in fecal discharges but usually in smaller numbers than *Esch. coli. Aer. aerogenes* and intermediate types of organisms are commonly present in soil and in waters polluted sometime in the past. Another subgroup comprises plant pathogens and other organisms of indefinite taxonomy about whose habitat information is limited. All the subgroups may be found in sewage and in polluted waters. *Esch. coli* is therefore frequently referred to as "fecal coli"; the I.A.C. group as "nonfecal." It must be remembered, however, that these terms are only relative.

Survival Times

Available information indicates that organisms of the I.A.C. group tend to survive longer in water than do fecal coliform organisms. The I.A.C. group also tends to be somewhat more resistant to chlorination than *Esch. coli* or the commonly occurring bacterial intestinal pathogens. Because of these and other reasons, the relative survival times of the coliform subgroups may be useful in distinguishing recent from less recent pollution. In waters recently contaminated with sewage, it is expected that fecal coliform organisms will be present in numbers greater than those of the I.A.C. subgroup. But in waters that have been contaminated for a considerable length of time or have been insufficiently chlorinated, organisms of the I.A.C. subgroup may be more numerous than fecal coliform organisms.

Differentiation of Organisms

Because various members of the coliform group normally grow in diverse natural habitats, attempts have been made to differentiate the population in polluted waters according to their original sources. In his pioneer work, MacConkey defined the aerogenes group in terms of certain fermentation characteristics, ability to produce indole, and reaction in the Voges-Proskauer test. Many contributed to the development of techniques and laboratory data that differentiated the coliform group on the basis of indole production, methyl red and Voges-Proskauer reactions, and citrate utilization (IMViC tests) into the *Esch. coli*, aerogenes, intermediate, and irregular subgroups. The Eijkman test was further developed to distinguish organisms of fecal origin from those of nonfecal origin by increased temperature incubation.

Sanitary Significance

Information on the sanitary significance of the various types of coliform organisms is incomplete. In relation to untreated waters, however, the present position may be thus stated:

Fecal coliform organisms (*Esch. coli*) may be considered indicators of recent fecal pollution. No satisfactory method is currently available for differentiating fecal coliform organisms of human and animal origin. Therefore, it is necessary to consider all fecal coliform organisms as indicative of dangerous contamination.

In the absence of fecal coliform organisms, the presence of I.A.C. group organisms in untreated waters may be the result of relatively less recent fecal pollution, soil runoff water, or infrequently, fecal pollution containing only the I.A.C. group.

In general terms, the presence of fecal coliform organisms indicates recent and possibly dangerous pollution. The presence of I.A.C. organisms suggests less recent pollution or reveals the existence of defects in water treatment or distribution.

Summary

The presence of any type of coliform organism in treated drinking water suggests either inadequate treatment or access of undesirable materials to the water after treatment. Although there are some differences between strain and subgroup organisms with regard to survival under natural conditions and resistance to chlorination, in general all the coliform organisms exhibit survival and resistance patterns in the same order of magnitude. The presence of coliform organisms (as defined earlier) in treated water calls for definitive action for their elimination.

Insofar as bacterial pathogens are concerned, the coliform group is considered a reliable indicator of the adequacy of treatment. As an indicator of pollution in drinking water supply systems, and indirectly as an indication of protection provided, the coliform group is preferred to fecal coliform organisms (*Esch. coli*). Whether these considerations can be extended to include rickettsial and viral organisms has not been definitely determined.

Fecal Streptococci as Indicators of Pollution

Fecal streptococci appear to be characteristic of fecal pollution, being consistently present in both the feces of all warm-blooded animals and in the environment associated with animal discharges. They do not multiply in streams or surface waters to yield overgrowths as sometimes occur with the coliform group. So far as is currently known, they are rare in soil or on vegetation not subject to continued fecal pollution. Therefore, the presence of fecal streptococci in a water indicates fecal pollution with the density equal to those originally present or reduced by natural purification processes.

By careful analysis of the streptococcal species present, the source of the fecal pollution can be estimated. For example: predominating strains of *Streptococcus fecalis* indicate human fecal pollution; *S. bovis* and *S. acidominimus* predominate in bovine excrement but are rarely present in human feces (about 0.4 percent of Streptococcus density); while in porcine excretal material, the species are about one-third *S. fecalis* (atypical types), one-third *S. bovis* and one-fourth *S. acidominimus*. Thus, it may be possible to separate human from other animal pollution and further studies of various animal excrement may permit further interpretations.

Improved methods and media are urgently needed for the analysis of streptococcal group. Investigations on the distribution of the various species of streptococci in nature should be diligently pursued. Azide Dextrose—EVA—multiple-tube procedure yields good results with the streptococci species present in humans but is relatively inefficient for the analysis of fecal streptococci present in other animals. The Slanetz MF procedure yields a few more species. The KF streptococcus medium and biochemical test procedures appear to offer promise of a more complete enumeration of fecal streptococci.

The streptococcus group in potable waters which are not chlorinated or which are in surface waters to be treated, appears to have certain advantages as indicator organisms in the interpretation of the type of pollution present. However, they do not appear to have any advantage over the coliform group in the examination of adequately chlorinated potable water.

Enteric Viruses in Water

Enteric viruses (infectious hepatitis, poliomyelitis, Coxsackie, and ECHO) should be considered as waterborne infectious agents. Epidemiological evidence indicates that treated water from a public supply is not a frequent carrier of such organisms. Clarke and Chang have recently reviewed both the published reports on outbreaks of infectious hepatitis and poliomyelitis and laboratory evidence on the resistance of various enteric viruses.

An estimated 20,000 to 40,000 cases of infectious hepatitis were reported in Delhi, India (1955–56), attributable to treated municipal water supply. The outbreak was not accompanied by noticeable increase of typhoid fever and other intestinal diseases. This indicates that, in practice, the virus of infectious hepatitis is more resistant to chlorine (chloramine) than are vegetative bacteria. On the strength of epidemiological evidence, poliomyelitis outbreak in Edmonton, Canada was attributed to the drinking (treated) water supply. Kelly and Sanderson showed (1958) that inactivation of enteric viruses (Polio virus I:MK 500 and Mahoney and Coxsackie B5) in water at pH 7, and 25° C requires a minimum free residual chlorine of 0.3 mg/1 for at least 30 minutes. At higher pH levels or lower temperatures, either more chlorine or longer contact time is required. The same authors (1960) showed that for the same viruses in water at 25° C and a pH of 7, a concentration of at least 9 mg/1 combined residual chlorine is necessary to inactivate with a contact period of 30 minutes; of 6 mg/1 with a 1-hour contact time; 0.5 mg/1 with a contact period of more than 7 hours.

Sabin found 10^4 TcD. of polio virus per gram of feces in human stools. Neefe *et al.* estimated there were 10^1 to 10^3 infectious doses of infectious hepatitis virus per gram of feces from human cases. Other estimations of viral content in feces have been in the same order of magnitude or less. Human feces normally contain 10^6 to 10^{10} coliforms bacteria per gram. An estimated mean value is 10^9 coliforms per gram. Because nearly all feces contain coliform organisms and only a relatively small portion (2 to 20 percent) contribute pathogenic virus, domestic sewage normally contains approximately 10,000 times as many coliforms as virus. Virus populations in sewage and polluted waters are subject to die-aways due to aging, adsorption, and sedimentation, dilution, and various undetermined causes. It is likely, therefore, that the virus content of polluted surface waters, wells, etc., is quite low when judged on the basis of the coliform-virus ratio. This relatively low virus content may account for the apparent paucity of virus infections attributed to such sources. The possibility of waterborne epidemics remains, and the efficacy of various water treatment processes including high free chlorine dosages and increased contact times should be further investigated.

Virology techniques have not yet been developed to a point where virus enumerations can be recommended as a routine procedure in microbiological examination of drinking water. Development of methodologies to permit such examination is currently under investigation but may require extended periods of study before perfection. The objectives of a research program under which several laboratories could cooperate should include the accumulation of sufficient data and the development of methodologies on which to base standards. In the interim, control laboratories having access to facilities for virus isolation and identification should be encouraged to utilize the best available procedures for evaluating the occurrence of enteroviruses in treated waters.

C—PHYSICAL CHARACTERISTICS

Turbidity, color, and odor requirements are easily attained during general use by properly designed and operated treatment plants and distribution systems. Failure to meet these requirements is an indication of either inadequate treatment facilities or improper operation of the system. Supplies used without treatment should also meet these requirements. It should not be implied that these turbidity limits represent acceptable effluent standards for water treatment plants. Such plants should routinely produce water with a turbidity of less than one unit.

Although these tests do not directly measure the safety of the water, they are related to consumer acceptance of the water. The levels of 5 units of turbidity, 15 units of color, and a threshold odor number of 3 are levels at which these characteristics become objectionable to a considerable number of people. Experience has shown that under such circumstances, many people turn to alternate supplies which may be less safe.

D—CHEMICAL CHARACTERISTICS

INTRODUCTION

In its report, the Advisory Committee defined guidelines which were used in developing the standards. The following pages present detailed data and the reasoning used in reaching the various chemical limits.

In general, "grounds for rejection" limits are based on the fact that the substances enumerated represent hazards to the health of man. In arriving at specific limits, the total environmental exposure of man to a stated specific toxicant has been considered. The Committee has attempted to set limits at the lowest practical level in order to minimize the amount of a toxicant contributed by

water, particularly when other sources such as milk, food, or air are known to represent the major exposure of man.

The limits, which should not be exceeded when more suitable water supplies can be made available, are based on factors which render a supply less desirable for use. These considerations relate to materials which impart objectionable taste and odor to water, render it economically or aesthetically inferior, or are toxic to fish or plants. In one instance (Carbon Chloroform Extract), the limit is expected also to have utility as a generalized procedure for limiting toxic exposure to organic chemicals.

The Drinking Water Standards are regarded as a standard of quality which is generally attainable by good water quality control practices. Poor practice is an inherent health hazard. It has been the policy of the Committee to set limits which are not so low as to be impracticable nor so high as to encourage pollution of water.

No attempt has been made to prescribe specific limits for every toxic or undesirable contaminant which might enter a public water supply. While the Committee is fully cognizant of the need for continued attention to chemical contaminants of water, the Standards are limited to recognized need. Standards for innumerable substances would require an impossible burden of analytical examination.

ALKYL BENZENE SULFONATE

(Anionic Surfactant)

The surfactant is a synthetic organic chemical having high residual affinity at one end of its molecule and low residual affinity at the other. Its vigorous surface activity justifies not only its name but its use as a principal ingredient of modern household detergents. Surfactants may be divided into two broad chemical classifications, ionic and nonionic. Ionic types may be either anionic (−) or cationic (+). Alkyl benzene sulfonate is a typical anionic surfactant.

Contamination of drinking water supplies with surfactants results from their disposal, as household and industrial wastes, into sources of raw water. Such contamination is appearing in supplies from both surface and ground waters. Other potential sources of human intake of surfactants are inadequately rinsed cooking and household utensils and dinnerware and food.

More than 75 percent of the surfactants in household detergents are of the anionic type. Alkyl aryl sulfonates account for almost three-quarters of these, the remainder being mostly alkyl sulfates. Next in extent of such use are the nonionics, the cationics making up only a small percentage. Hence, the anionic group comprises the specific materials of this type most apt to be present in raw water

supplies if any at all are present. The principal agent in this anionic group is the sodium salt of the sulfonation product of dodecylbenzene, an alkyl aryl sulfonate, termed alkyl benzene sulfonate or simply ABS. It is largely for this reason that the degree of detergent contamination is established currently in terms of the concentration of alkyl benzene sulfonate (ABS), for which quantitative determination can be made by practical and reasonably satisfactory laboratory procedures.

In general, commercial ABS is produced by condensing polypropylene (typically the tetrapolymer) with benzene, followed by a distillation cut to yield a reproducible product. ABS is thus a controlled mixture of isomers and homologues of dodecylbenzene, which upon sulfonation may be represented by the following typical structure:
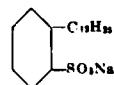
Concentrations of anionic surfactants found in drinking waters have ranged from 0 to 2.6 mg/1 in well water supplies and from 0 to 5 mg/1 in river water supplies. In one instance, a municipal water supply contained 5 mg/1 when a period of drought necessitated use of an impounded, highly purified sewage treatment plant effluent as a raw water supply.

In a study made for the purpose, 10 percent of those using water containing less than 1 mg/1 anionic sulfonated detergents complained of an off-taste, whereas all those using water containing 1.5 mg/1 complained of an off-taste. Frothing was also a common complaint occurring most frequently at concentrations of 1 mg/1 and above. The off-taste has been described as oily, fishy, or perfume-like. ABS itself is essentially odorless. The odor and taste characteristics are likely to rise from the degradation of products of other wastes rather than from ABS. The concentration of ABS in municipal sewage is of the order of 10 mg/1. Thus waters containing ABS are likely to be at least 10 percent of sewage origin for each mg ABS/1 present.

From the basic toxicologic point of view, there are two reports which are especially pertinent to the present consideration.

1. The Toxicologic Subcommittee of the Food Protection Committee of the Food and Nutrition Board, National Research Council, published a comprehensive report in 1956 bearing on the question of surfactants in food. Reviewing extensively the acute and chronic toxicity studies which have been reported on these chemicals, they found that there appears to be little specific relationship of toxicity

to surface activity (reduction of interfacial tension). In conclusion, it was stated that:

(a) There are no toxic effects common to all surfactants.

(b) Surface activity per se is not a measure of toxicity.

(c) The safety of each surfactant used in food must be determined separately.

The report pointed out that surfactants may occur fortuitously in some foods in amounts of a few parts per million and that: "It appears probable that the interfacial tension existing in the digestive tract of a healthy human is so low that it will not be further lowered by the small amounts of synthetic surfactants which may be present in food."

2. In a report on an investigation dealing with the chronic and subacute toxicity for rats of several surface-active agents, among which was sodium alkyl aryl sulfonate, Fitzhugh and Nelson declared that: "The toxic effects of the surface-active agents studied in the experiments were produced by irritation of the gastrointestinal tract .10,000 ppm or more in the diet). To an extent which depended on the concentration of the surface-active agents in the diet, this irritation prevented proper nutrition. In severe cases of irritation, death resulted.

It is recommended that alkyl benzene sulfonate (ABS) in drinking water be limited to 0.5 mg/1, inasmuch as higher concentrations may cause the water to exhibit undesirable taste and foaming. Concentrations of ABS above 0.5 mg/1 are also indicative of questionably undesirable levels of other sewage pollution.

An ABS concentration of 0.5 mg/1 in drinking water, in terms of a daily adult human intake of 2 liters, would give a safety factor of the order of 15,000, calculated on the results of subacute and 2-year tests on rats fed diets containing ABS. In these rat studies, it was found that levels of ABS in the diet of 0.5 percent and below produced no discernible physiological, biochemical, or pathological deviations from normal.

Human experience (6 subjects) with oral doses of purified ABS of 100 mg (equivalent to 2 liters of water containing 50 mg ABS/1) daily for 4 months led to no significant evidence of intolerance.

ANTIMONY*

Due to the limited knowledge concerning the properties of the various antimony compounds and the few instances reported in which antimony in water constitutes a problem, antimony was not considered for inclusion in the U.S. Public Health Service Drinking Water Standards, 1962.

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*Not contained in PHS Drinking Water Standards, but these limits were determined by the Bureau of Medicine and Surgery, the U.S. Public Health Service, and other authorities

However, antimony contamination of the water supply at a military installation prompted a review and investigation of the problem. The antimony levels herein stated were formulated by the Bureau of Medicine and Surgery upon consultation with the U.S. Public Health Service, National Research Council, and numerous other authorities.

Potassium antimony tartrate (tartar emetic) is one of the oldest medicinal metallic preparations, but its apparent toxicity has resulted in declining use in recent years. Toxic reactions are similar to arsenic reactions and include generalized irritation, depression and occasional coma, and collapse from systemic effects. The nausea and emetic properties of antimony compounds, due to irritation of the gastric and intestinal mucosa, represent a distinct safeguard against oral ingestion of these materials. Fatal doses cannot accurately be estimated due to the emetic action but literature does record deaths from doses of 100 mg or more.

Antimony poisoning in children as a result of drinking pink lemonade which had been stored overnight in an agate pot was reported in 1958 (Werrin). Symptoms were primarily nausea and intense vomiting, severe abdominal pain, and diarrhea.

Antimony and arsenic are similar metals. However, antimony is considered to be, with respect to its inorganic compounds, much less toxic than similar arsenic compounds. This statement does not hold true for organic compounds; as an example, whereas antimony trioxide has a lethal oral dose for the rat greater than 20,000 mg/kg body weight, that of the tartrate is from 50–120 mg/kg for various small animals. Corresponding data for arsenic trioxide vary from 13–140 mg/kg for various animal species.

Available information on the chronic toxicity of antimony relative to that of arsenic indicates that the chronic toxicity, although slightly less, is not remarkably less than that of arsenic.

It is the opinion of the U.S. Public Health Service that if the antimony limit does not routinely exceed 0.05 ppm, there will not be a hazard to health. If it should on occasion reach 0.1 ppm, there should not be cause for alarm. It is, of course, desirable that over long-time periods, the presence of this metal be kept to below the level recommended for arsenic, namely, 0.01 ppm.

ARSENIC

The widespread use of inorganic arsenic in insecticides and its presence in animal foods, tobacco, and other sources, make it necessary to set a limit on the concentration of arsenic in drinking water.

Normal human blood contains approximately 0.064 mg of arsenic per 100 ml, whereas urine may contain from trace amounts up to 5 mg per day. Arsenic is found in many foods in varying amounts, occurring naturally in some foods and introduced in others

as in pork and turkey and appears in poultry feeds or as a pesticide spray. Shellfish and crustaceans may contain up to 170 ppm, but it is suspected that assimilation of arsenic from this source is limited. Vegetables and fruits (and wine) may contain varying small amounts. The tolerance for arsenic on sprayed fruits and vegetables set by the Food and Drug Administration is 3.5 ppm. Neither trivalent nor pentavalent arsenic is known to be an essential or beneficial element, and the body is not known to be dependent on a daily intake.

The toxicity of arsenic is well-known and the ingestion of as little as 100 mg usually results in severe poisoning. Chronic poisoning from arsenic may be insidious and pernicious. A considerable proportion is retained at low intake levels. A single dose may require 10 days for complete disappearance and this slow excretion is in part the basis for its cumulative effects.

Both trivalent and pentavalent arsenic are easily absorbed from the gastrointestinal tract and lung, and become distributed throughout the body tissues and fluids. The toxicity of the pentavalent form is believed to be due to its reduction to the trivalent state. Inorganic arsenicals are potent inhibitors of the intracellular SH enzymes involved in cellular oxidations. The concentration of arsenic in kidney, liver, and the walls of the intestine can lead to serious consequences.

Recent evidence supports the view that arsenic may be carcinogenic. Industrial workers in a plant manufacturing arsenic powder were exposed to arsenic dust and showed a higher incidence of skin and lung cancer than other occupational groups. Ulceration of the nasal septum appears to be a common finding among workers exposed to inorganic arsenic. The incidence of skin cancer has also been reported to be unusually high in areas of England where arsenic was present in drinking water at a level of 12 mg/1.

Arsenic concentrations of from 2 to 4 mg/1 are reported not to interfere with the self-purification of streams, nor have arsenic concentrations of 3 to 14 mg/1 been harmful to mayfly nymphs and 10 to 20 mg/1 to dragon and damsel flies. Bass have tolerated 6 mg/1 for 232 hours. A concentration of 15 mg/1 proved toxic to crappies and blue gills, and 20 mg/1 (as sodium arsenite) proved harmful to minnows after 36 hours exposure.

The U.S. Public Health Service Drinking Water Standards for 1946 established an arsenic limit of 0.06 mg/1. In light of our present knowledge concerning the potential health hazard from the ingestion of inorganic arsenic, the concentration of arsenic in drinking water should not exceed 0.01 mg/1 and concentrations in excess of 0.05 mg/1 are grounds for rejection of the supply.

BARIUM

Reference to a limiting concentration for barium in the Public Health Service Drinking Water Standards of 1946 is confined to "salts of barium . . . shall not be added for water-treatment purposes." No reference to barium is made in the International Drinking Water Standards of 1958. Barium occurs naturally in some mineral springs as the carbonate salt.

Barium is recognized as a general muscle stimulant, including especially the heart muscle. The fatal does for man is considered to be from 0.8–0.9 g as the chloride (550–600 mg Ba). Most fatalities have occurred from mistaken use of barium salts incorporated in rat poison. Barium is capable of causing nerve block and in small or moderate doses produces transient increase in blood pressure by vasoconstriction. Aspirated barium sulfate has been reported to result in granuloma of the lung and other sites in man. Thus, evidence exists for high acute toxicity of ingested soluble barium salts, and for chronic irreversible changes in tissues resulting from the actual deposition of insoluble forms of barium in sufficient amounts at a localized site. On the other hand, the recent literature reports no accumulation of barium in bone, muscle, or kidney from experimentally administered barium salts in animals. Most of the administered dose appeared in the liver with far lesser amounts in the lungs and spleen. This substantiates the prior finding of no measurable amounts of barium in bones or soft tissues of man. Later, more accurate analysis of human bone (British) showed 7 ug Ba/g ashed sample, but no increase in bone barium occurred from birth to death. Small amounts of barium have been shown to go to the skeleton of animals when tracer amounts of barium-140 were used, but no determinations of barium have been made in animals to which barium had been repeatedly administered for long periods.

No study appears to have been made of the amounts of barium that may be tolerated in drinking water or of effects from prolonged feeding of barium salts from which an acceptable water standard may be set. A rational basis for a water standard may be derived from the threshold limit of 0.5 mg Ba/m' air set by the American Conference of Governmental Industrial Hygienists by procedures that have been discussed. By making reasonable assumptions as to retention of inhaled barium dusts and absorption from the intestine (and including a safety factor) 1 mg/1 is derivable as a limit that should constitute a "no effect" level in water. Concentrations of barium in excess of 1 mg/1 are grounds for rejection of the supply because of the seriousness of the toxic effects of barium on the heart, blood vessels, and nerves.

Limits and Ranges Relative to Barium Standard

1. Average U.S. urban air concentration ---------------------------- 0.025 ug Ba/m³
2. Surface and ground waters -------------------------------- Not usually present
3. Concentrations harmful to fish ------------------------------- 400 mg/1
4. Concentrations harmful to Daphnia Magna ------------------ 30 mg/1
5. Barium content of Brazil nuts (Only food with barium in considerable amounts) --------------------------------------- 0.06-0.3%
6. Concentrations of various natural anions required to reach solubility product of barium salts:

	Solubility product moles/l at M° C	Milligrams anion required per liter to attain solubility product of 1 mg barium
BaSO₄	1×10^{-10}	1.3 SO₄
BaCO₃	8×10^{-9}	66 CO₃
BaF₂	1.7×10^{-6}	9000 F

The solubility of relatively insoluble barium salts such as the sulfate may be increased in the presence of iron, magnesium, and aluminum salts, so that in the presence of the latter, calculations of solubility from the solubility product may not apply.

CADMIUM

As far as is known, cadmium is biologically a non-essential, nonbeneficial element. On the other hand, cadmium is recognized to be an element of high toxic potential. Slight cognizance has been taken of this in water quality control as evidenced by the fact that only the USSR, and in the United States, North Dakota, have set a permissable water standard for cadmium, 0.1 mg/1 by the former and 0.4 mg/1 as a tentative value by the latter. Recognition of the serious toxic potential of cadmium when taken by mouth is based on: (a) poisoning from cadmium-contaminated food and beverages; (b) epidemiologic evidence that cadmium may be associated with renal arterial hypertension under certain conditions; (c) long-term oral toxicity studies in animals.

The possibility of cadmium being a water contaminant has been reported in 1954; seepage of cadmium into ground water from electroplating plants has resulted in cadmium concentrations ranging from 0.01 to 3.2 mg/1. Other sources of cadmium contamination in water arise from zinc-galvanized iron in which cadmium is a contaminant.

Several instances have been reported of poisoning from eating substances contaminated with cadmium. A group of school children were made ill by eating popsicles containing 13 to 15 mg/1 cadmium. This is commonly considered the emetic threshold concentration for cadmium. It has been stated that the concentration and not the absolute amount determines the acute cadmium toxicity; equivalent concentrations of cadmium in water are likewise considered more toxic than equivalent concentrations in food probably because of the antagonistic effect of components in the food.

Chronic oral toxicity studies in rats, in which cadmium chloride was added to various diets at levels of 15, 45, 75, and 135 ppm cadmium, showed marked anemia, retarded growth, and in many instances death at the 135 ppm level. At lower cadmium levels, anemia developed later; only one cadmium-fed animal had marked anemia at the 15 ppm level. Bleaching of the incisor teeth occurred in rats at all levels except in some animals at 15 ppm. A low protein diet increased cadmium toxicity. A maximal "no effect" level was thus not established in the above studies. A dietary relation to cadmium toxicity has been reported by others.

Fifty ppm cadmium administered as cadmium chloride in food and drinking water to rats resulted in a reduction of blood hemoglobin and lessened dental pigmentation. Cadmium did not decrease experimental caries.

In a study specifically designed to determine the effects of drinking water contaminated with cadmium, 5 groups of rats were exposed to drinking water containing levels from 0.1 to 10 mg/1. Although no effects of cadmium toxicity were noted, the content of cadmium in the kidney and liver increased in direct proportion to the dose at all levels including 0.1 mg/1. At the end of 1 year, tissue concentrations approximately doubled those at 6 months. Toxic effects were evident in a 3-month study at 50 mg/1.

Thus, all levels of dietary cadmium so far tested have shown cadmium accumulation in the soft tissues down to and including 0.1 mg/1 (in drinking water). Because the presence of minute amounts $(5 \times 10^{-9} M)$ of cadmium in rat liver mitochondria has been shown to interfere with an important pathway of metabolism (uncoupled oxidative phosphorylation), and because suspicion has been cast on the presence of minute amounts of cadmium in the kidney as responsible for adverse renal arterial changes in man, concentrations of cadmium in excess of 0.01 mg/1 in drinking water are grounds for rejection of the supply.

Further evidence that a concentration of 0.01 mg/1 can be tolerated is found in a study made on long-continued cadmium absorption, without history of symptoms, in individuals whose drinking water had an average cadmium content of 0.047 mg/1.

Limits and Ranges Relative to Cadmium Water Standard

U.S. average urban air concentration (1954–56)................... 0.005 ug Cd/m³
U.S. range urban air concentration (1954–56)................... 0–0.599 ug Cd/m³
Cd concentration lethal to minnows............................ 1,000 mg/l
Cd concentration lethal to stickleback....................... 0.20 mg/l
Cd concentration in tobacco.................................. Not known
Cd concentration in foods................................... Not known

CARBON CHLOROFORM EXTRACT

The use of Carbon Chloroform Extract (CCE) as a practical measure of water quality and as a safeguard against the intrusion of excessive amounts of potentially toxic material into water has been discussed elsewhere. It is proposed as a technically practical procedure which will afford a large measure of protection against the presence of undetected toxic materials in finished drinking water.

The most desirable condition is one in which the water supply delivered to the consumer contains no organic residues. Residual organic matter in the treated water clearly represents man-made or natural pollutants which have not been removed in water treatment or material such as lubricants inadvertently introduced by the water plant. In view of a general inability to clearly define the chemical and toxicological nature of this material, it is most desirable to limit it to the lowest obtainable level. Analysis of data available indicates that water supplies containing over 200 micrograms CCE/1 of water represent an exceptional and unwarranted dosage of the water consumer with ill-defined chemicals. It is recommended that 200 ug CCE/1 be the limiting concentrations in drinking water.

CHLORIDE, SULFATE, AND DISSOLVED SOLIDS

The importance of chloride, sulfate, and dissolved solids as they affect water quality hinges upon their taste and laxative properties. There is evidence that excessive amounts of these constituents cause consumer reactions which may result in individual treatment or rejection of the supply. Therefore, limiting amounts for these chemical constituents have been included in the Standards. The bases for developing these limits are described below.

Taste

The literature contains a number of reports on the taste threshold of various salts. Whipple, using a panel of 10 to 20 persons, found the range of concentration of various salts detected as shown in table 1. Richter and MacLean studied the response of a larger panel to sodium chloride in distilled water. Table 2 summarizes their results.

Lockhart, Tucker, and Merritt also studied the taste threshold of the ions in distilled water by studying the effect of ions in water on the flavor of brewed coffee. Using a triangular test with panels

of 18 or more, they found results which are summarized in table 3. In the Triangular taste test, the panel members are asked to taste three samples. Two of the samples may contain either the salt being tested or distilled water, while the third is different from the other two. The panel member is asked to identify the odd one. Using this test procedure, the threshold concentration is arbitrarily defined as the concentration at which the number of correct separations is 50 percent above the chance probability of one-third correct separations, i.e., when two-thirds of the panel make the separations correctly.

The results shown in table 1 and table 3 are in surprisingly good agreement, considering the difference in methods used. The Richter and MacLean study found taste thresholds considerably below those of the other two studies. They support reasonably well the recommended limits of 250 mg/1 for chloride and sulfates and 500 mg/1 for total solids.

It should be emphasized that there may be a great difference between a detectable concentration and an objectionable concentration of the neutral salts. The factor of acclimatization is particularly important. More than 100 public supplies in the United States provide water with more than 2,000 mg/1 of dissolved solids. Newcomers and casual visitors would certainly find these waters almost intolerable and, although some of the residents use other supplies for drinking, many are able to tolerate if not to enjoy these highly mineralized waters.

Relatively little information is available on consumer attitudes toward mineralized water. In this connection, the findings of a survey made by the California State Department of Public Health showed that in five communities where the public supplies were highly mineralized, about 40 percent of the families surveyed purchased bottled water and about 50 percent stated they were dissatisfied with the water. These supplies had dissolved solids contents in range of 500 to 1,750 mg/1. Calcium, sulfate, and magnesium were the dominant ions present, with sulfate concentrations in the range of 300 to 700 mg/1.

The taste threshold for magnesium is said to be 400–600 mg/1.

Laxative Effects

Both sodium sulfate and magnesium sulfate are well known laxatives. The laxative dose for both Glauber salt (Na₂SO₄·10H₂O) and Epsom salt

(MgSO₄·7H₂O) is about 2 grams. Two liters of water with about 300 mg/l of sulfate derived from Glauber salt, or 390 mg/l of sulfate from Epsom salt, would provide this dose. Calcium sulfate is much less active in this respect.

This laxative effect is commonly noted by newcomers and casual users of waters high in sulfates. One evidently becomes acclimated to use of these waters in a relatively short time.

The North Dakota State Department of Health has collected information on the laxative effects of water as related to mineral quality. This has been obtained by having individuals submitting water samples for mineral analysis complete a questionnaire which asks about the taste and odor of the water, its laxative effect (particularly on those not accustomed to using it), its effect on coffee, and its effect on potatoes cooked in it.

Peterson and Moore have analyzed part of the data collected, particularly with regard to the laxative effect of the water.

Peterson found that, in general, the waters containing more than 750 mg/l of sulfate showed a laxative effect and those with less than 600 mg/l generally did not. If the water was high in magnesium, the effect was shown at lower sulfate concentrations than if other cations were dominant. Moore showed that laxative effects were experienced by the most sensitive persons, not accustomed to the water, when magnesium was about 200 mg/l and by the average person when magnesium was 500–1,000 mg/l.

Moore analyzed the data as shown in table 4. When sulfates plus magnesium exceed 1,000 mg/l or

dissolved solids exceed 2,000 mg/l, a majority of those who gave a definite reply indicated a laxative effect.

Other Effects

Highly mineralized water affects the quality of coffee brewed with it. Lockhart, Tucker, and Merritt found that from 400 to 500 mg/l of chlorides or 800 mg/l of sulfate as MgSO₄ affected the taste of coffee. Gardner studied the effect of ions in water on the brewing time of drip coffee and hence on the quality of the product since prolonged contact with the grounds makes the coffee bitter. Sodium had a distinct deleterious effect.

At high enough mineral concentration, water becomes completely unusable for drinking. These concentrations are in the range above 5,000 mg/l and need not be considered here.

Conclusion

It is recommended that waters containing more than 250 mg/l of chlorides or sulfates and 500 mg/l of dissolved solids not be used if other less mineralized supplies are available. This is influenced primarily by considerations of taste. Cathartic effects are commonly experienced with water having sulfate concentrations of 600 to 1,000 mg/l, particularly if much magnesium or sodium is present. Although waters of such quality are not generally desirable, it is recognized that a considerable number of supplies with dissolved solids in excess of the recommended limits are used without any obvious ill effects.

Table 1.—Range of concentration of various salts detected by taste in drinking water by panel of 10 to 20 persons

Salt	Concentration detected—mg/l			
	Median		Range	
	Salt	Anion	Salt	Anion
KCL	525	250	350–600	167–286
NaCl	300	182	200–450	121–274
CaCl₂	250	160	150–350	96–224
MgCl₂	500	372	200–750	149–560
Sea water		¹ 300		¹ 150–600
NaSO₄	350	237	250–550	169–372
CaSO₄	525	370	250–900	177–635
MgSO₄	525	419	400–600	320–479

¹ In terms of mg/l chloride.

Source: Whipple, G. C., The value of pure water. Wiley (1907).

Table 2.—Taste threshold concentrations of panel of 53 adults for NaCl

	Concentrations mg/1					
	Mean		Median		Range	
	NaCl	Cl	NaCl	Cl	NaCl	Cl
Difference from distilled water noted	160	97	100	61	70-600	42-364
Salt taste identified	870	530	650	395	200-2,500	120-1,215

Table 3.—Taste threshold concentration of salt and ions in water

	Threshold concentration—mg/1		
	Salt	Cation	Anion
NaCl	345	135	210
KCl	650	340	310
CaCl₂	347	125	222
MgSO₄	500	100	400
NaHCO₃	1,060	290	770

Source: Lockhart, E. E., Tucker, C. L., and Merritt, M. C. The effect of water impurities on the flavor of brewed coffee, Food Research, 20, 598-605 (1955).

Table 4.—Solids and ion concentration of wells as related to presence or absence of laxative effects

Determination	Range mg/1	Number of wells in range	Laxative		Effects present not stated	Percent of yes answers [1]
			Yes	No		
Total dissolved solids	0-1,000	51	5	37	9	12
	1,000-2,000	72	12	45	15	21
	2,000-3,000	62	25	21	16	54
	3,000-4,000	30	13	11	6	54
	over 4,000	33	14	4	15	78
Magnesium plus sulfate	0-200	51	9	34	8	21
	200-500	45	7	27	11	21
	500-1,000	56	11	38	17	28
	1,000-1,500	36	18	10	8	64
	1,500-2,000	14	6	4	4	60
	2,000-3,000	21	13	3	5	81
	over 3,000	14	5	1	8	83
Sulfate	0-200	56	10	36	10	22
	200-500	47	9	26	10	24
	500-1,000	56	13	26	17	33
	1,000-1,500	34	16	10	8	62
	1,500-2,000	16	9	4	3	69
	2,000-3,000	20	9	3	8	75
	over 3,000	8	3	0	5	100

[1] This percentage is based only on the total of yes and no answers. It is probable that a large proportion of the wells for which no statements were made were not regularly used as water supplies.

Source: Moore, Edward W., Physiological effects of the consumption of saline drinking water, a progress report to the Subcommittee on Water Supply of the Committee on Sanitary Engineering and Environment. National Research Council (1962).

CHROMIUM

The limit of 0.05 mg/1 for chromium as hexavalent chromium ion appearing in the U.S. Public Health Service 1946 Drinking Water Standards was based on the lowest amount analytically determinable at the time it was established. At present, the level of chromate ion that can be tolerated by man for a lifetime without adverse effects on health is unknown. A family of 4 individuals is known to have drunk water for periods of 3 years at a level as high at 1 mg. chromate/1 without known effects on their health, as determined by a single medical examination. The family continued to drink the water which, when sampled later, contained 25 mg/1. No continued medical observation of these individuals was made.

When inhaled, chromium is a known cancerigenic agent for man. It is not known whether cancer will result from ingestion of chromium in any of its valence forms. According to Fairhall, trivalent chromium salts show none of the toxicity of the hexavalent form, particularly the highly insoluble salts. Trivalent chromium moreover, is believed not to be of concern in drinking water supplies.

Chromium is not known to be either an essential or beneficial element in the body.

The most recent study by MacKenzie, Byerrum, et al. was designed to determine the toxicity of chromate ion (and chromic ion) at various levels in the drinking water of rats. This study, like a number of previous ones, showed no evidence of toxic response after 1 year at levels from 0.45 to 25 mg/1 by the tests employed, viz., body weight, food consumption, blood changes, and mortality. However, significant accumulation of chromium in the tissues occurred abruptly at concentrations above 5 mg/1. Unfortunately, no study was made of the effect of chromate on a cancer-susceptible strain of animal. It would appear, however, from this and other studies of toxicity, that a concentration of 0.05 mg/1 is sufficiently low to cause no effect on health.

The possibility of dermal effects from bathing in water containing 0.05 mg/1 would likewise seem remote, although chromate is a recognized and potent sensitizer of the skin.

Chromium is not known to be a common or significant element in food sources. That which may be found in small quantities in foods is in trivalent form, is usually adventitious, and arises chiefly from cooking in stainless steel ware. Neither the amounts nor the assimilabili... are known to be of any hygienic significance.

Limits and Ranges Relative to Chromium Water Standards

Threshold range for color	1.4–11 mg/1
Threshold range for taste	1.4–25 mg/1
U.S. urban air concentration range (1954–56)	0–0.29 ug/m³
Average urban air concentration (1954–56)	0.007 ug/m³
Chromium content of cigarette tobacco	1.4 ug/cigarette
Chromium in foods cooked in stainless-steel ware	0–0.35 mg/100 g
Chromate concentration toxic to fish	5–200 mg/1
Chromate concentration toxic to Daphnia Magna	0.05 mg/1
Chromate concentration range in surface water	0–2.3 mg/1

CALCULATED MAXIMAL DAILY INTAKE OF CHROMIUM FROM VARIOUS SOURCES

(Approximate Values)

Food cooked in stainless-steel ware	10–25 ug
Water	2 ug
Air	0.3 ug
Cigarettes	10–15 ug

COPPER

In the Public Health Service 1942 Drinking Water Standards, the permissible concentration of copper in drinking water was raised from 0.2 mg/1 to 3.0 mg/1.

Copper is an essential and beneficial element in human metabolism, and it is well known that a deficiency in copper results in nutritional anemia in infants. The daily requirement for adults has been estimated to be 2.0 mg. The children of preschool age require about 0.1 mg daily for normal growth.

The average daily urinary excretion is in the order of 1.0 mg, the remainder being eliminated in the feces. Since the normal diet provides only a little more than is required, an additional supplement from water would ensure an adequate intake. The distribution of copper in the body is fairly uniform, except for the liver where it appears to accumulate.

Copper imparts some taste to water but individuals vary in the acuity of their taste perception and the detectable range varies from 1–5 mg/1. Small amounts are generally regarded as nontoxic

but large doses may produce emesis and prolonged oral administration may result in liver damage.

Inasmuch as copper does not constitute a health hazard but imparts an undesirable taste to drinking water, it is reasonable to establish the concentration of 1.0 mg/l as the recommended limit.

CYANIDE

The U.S. Public Health Service Drinking Water Standards for 1946 contain no limit for cyanide. Since 1946, standards have been developed for cyanide by other agencies as shown in the following tabulation.

Standard set by	Limit for cyanide mg/l
International Standards for Drinking Water, Geneva (1958)	0.01
Netherlands (1959)	0.01
USSR Standard (1951)	0.2
Ohio Water Pollution Control Board (1952)	0.15
Adv. Bd. Lake Erie-Ontario Sect. I.J.C. (1953)	0.1
N.Y. Water Pollution Control Bd. (1952)	0.1
Pacific N.W. River Basin (1952)	0.05

The cyanide standards appear to be based on the toxicity for fish and not for man, as is shown by a comparison that follows of the safe, toxic, and lethal doses for fish and for man. Cyanide in reasonable doses (10 mg or less) is readily converted to thiocyanate in the body. Usually lethal toxic effects occur only when the detoxifying mechanism is overwhelmed.

Oral toxicity of cyanide for man

Dosage	Response
2.9–4.7 mg/day	Noninjurious.
10 mg, single dose	Noninjurious.
19 mg in water	Calculated from threshold limit for air to be safe.
50–60 mg, single dose	Fatal.

Toxicity of cyanide for fish

Cyanide in mg/l	Time of exposure	Fish species	Response
0.05	120 hours	Trout	Death.
0.1–0.2	1–2 days	do	Do.
0.126	170 minutes	do	Overturned.
0.176		Bluegills, Sunfish	Toxic limit.
1.0	20 minutes	Trout	Death.
10.0	90 minutes	Carp	Do.
0.02	27 days	Trout	Survival.
0.4	96 hours	Bluegills	Do.
0.5	96 hours	Bullheads	Do.

Because proper treatment will reduce cyanide levels to 0.01 mg/l or less, it is recommended that concentrations in water be kept below 0.01 mg CN/l.

For the protection of the health of human populations, concentrations above 0.2 mg CN/l constitute grounds for rejection of the supply. This limit should provide a factor of safety of approximately 100 and is set at this level because of the rapidly fatal effect of cyanide. Proper chlorination under neutral or alkaline conditions will reduce cyanide to a level below the recommended limit. The acute oral toxicity of cyanogen chloride, the chlorination product of hydrogen cyanide, is approximately one-twentieth that of hydrogen cyanide.

FLUORIDE

Fluoride in drinking water will prevent dental caries. When the concentration is optimum, no ill effects will result and caries rates will be 60–65 percent below the rates in communities using water supplies with little or no fluoride.

Excessive fluoride in drinking water supplies produces objectionable dental fluorosis which increases with increasing fluoride concentration above the recommended upper control limits.[1] In the United States, this is the only harmful effect observed to result from fluoride found in drinking water. Other expected effects from excessively high intake levels

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[1] See Table I, following Article 5–32(5)(b)3 of Chapter 5.

are: (a) bone changes when water containing 8–20 mg fluoride per liter (8–20 ppm) is consumed over a long period of time; (b) crippling fluorosis when 20 or more mg of fluoride from all sources is consumed per day for 20 or more years; (c) death when 2,250–4,500 mg of fluoride (5,000–10,000 mg sodium fluoride) is consumed in a single dose.

The optimum fluoride level for a given community depends on climatic conditions because the amount of water (and consequently the amount of fluoride) ingested by children is primarily influenced by air temperature. Many communities with water supplies containing less fluoride than the concentration shown as the lower limit for the appropriate air temperature range[1] have provided fluoride supplementation. Other communities with excessively high natural fluoride levels have effectively reduced fluorosis by partial defluoridation and by change to a water source with more acceptable fluoride concentration.

IRON

Both iron and manganese are highly objectionable constituents in water supplies for either domestic or industrial use. The domestic consumer complains of the brownish color which iron imparts to laundered goods. Iron appreciably affects the taste of beverages.

The taste which iron imparts to water may be described as bitter and astringent. Individuals vary in their acuity of taste perception, and it is difficult to establish a level which would not be detectable for the majority of the population. A study by the Public Health Service indicates that the taste of iron may be readily detected at 1.8 mg/l in spring water and at 3.4 mg/l in distilled water.

The daily nutritional requirement is 1 to 2 mg but intake of larger quantities is required as a result of poor absorption. Diets contain 7 to 35 mg per day and average 16. The amount of iron permitted in water by quality control to prevent objectionable taste or laundry staining (as much as 0.3 mg/l) constitutes only a small fraction of the amount normally consumed and is not likely to have any toxicologic significance.

Whereas the U.S. Public Health Service 1946 Drinking Water Standards set a limit of 0.3 mg/l for iron and manganese combined, it is recommended that a limit be established for each and that the concentration of iron be limited to 0.3 mg/l.

LEAD

Lead taken into the body can be seriously injurious to health, even lethal, if taken in by either brief or prolonged exposure. Prolonged exposure to relatively small quantities may result in serious illness or death. Lead taken into the body in quantities in excess of certain relatively low "normal"

limits is a cumulative poison. Poisoning may result from an accumulation in the body of lead absorbed in sufficient quantities from any one or all of three common sources: food, air, and water, including that used in cooking and in beverages. A fourth, but variable source of intake is inhaled tobacco smoke. Except in certain occupational conditions, absorption of lead through the skin is not of general public health importance.

The total amount of lead taken into the body from these sources as modified by absorption and elimination, determines whether the sources of exposure have been excessive and produce poisoning, or may be tolerated without effect throughout a lifetime.

The daily intake of lead that may be tolerated without effect throughout each decade of life is not precisely known, but a value may be determined from the following information.

1. The amount of lead ingested in food and beverage by adults in good health in various parts of the United States has been shown by Kehoe and associates to vary from less than 0.1 mg to more than 2.0 mg/day with a mean value of about 0.32 mg/day. At these levels, excretion keeps pace with intake, and if any accumulation of lead occurs it is intermittent and of no hygienic significance.

2. When, under experimental condition, the daily intake of lead from all sources amounted to 0.5–0.6 mg over a long period of time (1 year or more), a small amount is retained in normal healthy adults but produced no detectable deviation from normal health. Indirect evidence from industrial workers exposed to known amounts of lead for long periods was consistent with these findings.

3. Appreciable increases in the daily intake of lead above 0.6 mg daily result in body accumulation at rates that increase as the daily dose increases. Extrapolations from data from balance experiments over a 5-year period indicate, but do not prove, that an intake appreciably in excess of 0.6 mg/day will result in the accumulation of a dangerous quantity of lead in the body during a lifetime.

4. The intake of lead from food sources is probably approaching an irreducible minimum; on the other hand, the number of sources and the extent of lead exposure are increasing. The atmosphere is one of these. Over the past decade, the amount of atmospheric lead in many cities has increased more than tenfold, from a few tens of micrograms (ug) per cubic meter (m^3) of air to more than 15 ug/m^3 in some cities on repeated occasions. The national average for urban atmosphere is presently 1.4 ug/m^3. Wide variations in these values exist throughout the nation because the sources are largely unregulated and are increasing at different rates in different areas from vehicular traffic. If the average daily intake of air of an adult is 30 cubic meters, then the daily addition to the body

[1] See Table I, following Article 5-32(3)(b)3 of Chapter 5.

burden of lead from the atmosphere could be of the order of several micrograms to a few tens of micrograms, depending on the location. This assumes a modest 10 percent retention of that which the individual inhales.

5. The amount of lead in cigarette tobacco smoke has been reported to be as high as 0.3 ug/puff. In a heavy smoker, a few micrograms per day could be added to the lead body burden assuming 10 percent retention of the total smoke inhaled.

Foods contain lead in widely varying amounts because of the natural and unavoidable content of lead in foods, the inevitable contamination with lead that results incidentally from processing and packaging, and the residue from insecticidal spraying and dusting. Certain foods, in particular those which are more seriously and unavoidably contaminated, are required by law to contain by analysis no more than a prescribed concentration of lead. The foods under regulation make up a relatively small portion of the average normal diet. Consequently, only partial control is exercised over the lead intake from food sources. The foods that contribute the greater portion of the diet contain concentrations of lead which are considered to be normal (that is, natural or incidental) but in any case unavoidable (under 0.2 ppm, and usually well under 0.1 ppm). The total intake of lead from these foods is governed by the quantity and quality of the food ingested, and by contamination with lead in the handling and preparation of the food.

The lead concentration in surface and in ground drinking water sources in the United States in 1940 ranged from traces to 0.04 mg/1, averaging 0.01 mg/1. It is now not uncommon to find the lead content of water in urban supplies to be from one-half to one-fifth this value, provided the water is not stored in tanks painted with oil-base lead paint (Type I) or provided that the piping and fixtures are not of lead or lead alloys. However, a principal source of lead in municipal drinking waters is lead pipe and goosenecks in house services and plumbing systems. The practice of using lead pipe is still permitted by many plumbing codes. Normal adults in the temperate zone drink quantities of water, ranging from less than 1 to more than 3 liters/day, the average being taken as 2 liters. This is in addition to the water used in cooking and in other beverages. Thus, water can contribute a substantial proportion of the total daily intake of lead, depending upon the concentration of lead therein, the environmental temperature, and physical exertion.

Inasmuch as three of the four sources of lead intake in the human body—ingested foodstuffs, inhaled atmosphere, and tobacco smoke—are for the most part unregulated in their lead content, and because the total daily intake of lead which results in progressive retention of lead in the human body appears to be less than twice the average normal intake of lead in adults in the United States, concentrations of lead in drinking water greater than 0.05 mg/1 constitute grounds for rejection of the supply.

In consonance with this limit is the reported finding that bacterial decomposition of organic matter is inhibited by lead concentrations at or above 0.1 mg/1. Lead in soft water is highly toxic to certain fish; 0.1 mg/1 is toxic to small sticklebacks, larger fish are somewhat less susceptible to lead. Calcium ion at a concentration of 50 mg/1 removes the toxic effect of 1 mg/1 lead for fish.

Limits and Ranges of Lead Affecting Health

Physiologically safe in water:
    Lifetime_____ 0.05 mg/1
    Short period, a few weeks__ 2-4 mg/1
Harmful range in water:
    Borderline_____ 2-4 mg/1 for 3 months.
    Toxic_____ 8-10 mg/1, several weeks.
    Lethal_____ Unknown, but probably more than 15 mg/1, several
                         weeks.

MANGANESE

There are two reasons for limiting the concentration of manganese in drinking water: (a) to prevent esthetic and economic damage, and (b) to avoid any possible physiologic effects from excessive intake.

It has been reported that minute amounts of manganese cause difficulty in water quality control. The domestic consumer finds that it produces a brownish color in laundered goods and impairs the taste of beverages including coffee and tea.

From the health standpoint, there are no data to indicate at what level manganese would be harmful when ingested. The principal toxic effects which have been reported are the results of inhalation of manganese dust or fumes. It has been estimated that the daily intake of manganese from a normal diet is about 10 mg. In animals, at least, it has been shown to be an essential nutrient, since diets deficient in manganese interfere with growth, blood, and bone formation and reproduction. Hepatic cirrhosis has been produced in rats when treated orally with very large doses. As far as is known, the neurologic effects of manganese have not been reported from oral ingestion in man or animal.

The principal reason for limiting the concentration of manganese is to provide water quality control and thus reduce the esthetic and economic problems.

The U.S. Public Health Service Drinking Water Standards (1946) state that iron and manganese together should not exceed 0.3 mg/1. In a survey of 13 States reporting on levels of manganese giving rise to water quality problems, only 3 States recommended levels as high as 0.2 mg/1, 2 permitted 0.15 mg/1 and 4 each permitted 0.1 mg/1 and 0.05 mg/1 respectively. Domestic complaints arise when the level of manganese exceeds 0.15 mg/1 regardless of iron content. Griffin, in reviewing the significance of manganese as chairman of the task group on "Manganese Deposition in Pipelines," quoted the belief of certain water utility men that water to consumers should be free of manganese. For some industries, this is imperative. However, Griffin believes that concentration of manganese could be tolerated by the average consumer at 0.01-0.02 mg/1.

In view of the above and the difficulty of removing manganese to residual concentrations much less than 0.05 mg/1, and measuring such concentrations, manganese concentrations should be limited to a maximum of 0.05 mg/1.

NITRATE

Serious and occasionally fatal poisonings in infants have occurred following ingestion of well waters shown to contain nitrate (NO_3). This has occurred with sufficient frequency and widespread geographic distribution to compel recognition of the hazard by assigning a limit to the concentration of nitrate in drinking water.

From 1947 to 1950, 139 cases of methemoglobinemia, including 14 deaths due to nitrate in farm well-water supplies, have been reported in Minnesota alone. Wastes from chemical fertilizer plants and field fertilization may be sources of pollution. The causative factor producing serious blood changes in infants was first reported in 1945 in polluted water containing 140 mg/1 nitrate nitrogen (NO_3-N) and 0.4mg/1 nitrite (NO_2) ion in one case; in the second case, 90 mg/1 nitrate nitrogen and 1.3 mg/1 nitrite ion. Since this report, many instances of similar occurrences have been recorded not only in this country but in Canada, Great Britain, Belgium, Germany, and other countries.

The International Drinking Water Standards of 1958 took cognizance of the problem in noting that ingestion of water containing nitrates in excess of 50 mg/1 (as nitrate) may give rise to infantile methemoglobinemia but have included no limit. A limit of 20 mg/1 nitrate nitrogen has been suggested in England. Elsewhere nitrate nitrogen concentrations in excess of 10-20 mg/1 are considered capable of producing cyanosis in infants. Various South American countries have recommended maximum permissible levels of from 0.5-226 mg/1 nitrate (NO_3) (0.1-51 mg/1 nitrate nitrogen).

Cases of infantile nitrate poisoning have been reported to arise from concentrations ranging from 15-250 or more mg/1 nitrate nitrogen (usually with traces of nitrite ion) in instances in which the water was analyzed up to 1952, according to Campbell. Campbell himself reported a case from ingesting water with 26.2 mg/1 as nitrate nitrogen (116 mg/1 nitrate ion).

According to methods of analysis commonly employed for nitrate in water, the presence of appreciable amounts of chloride would result in an erroneously low value for nitrate, and the presence of considerable amounts of organic matter would give an erroneously high value for nitrate. Insufficient attention has been given this important factor in evaluating permissible safe levels of nitrate in water.

Nitrate poisoning appears to be confined to infants during their first few months of life; adults drinking the same water are not affected but breast-fed infants of mothers drinking such water may be poisoned. Cows drinking water containing nitrate may produce milk sufficiently high in nitrate to result in infant poisoning. Both man and animals can be poisoned by nitrate if the concentration is sufficiently great.

Among the more acceptable hypotheses for the specificity of nitrate poisoning of infants is the following: the gastric, free acidity of infants is low (a pH of 4 or greater), permitting the growth of nitrate-reducing flora in a portion of the gastro-intestinal tract from which nitrite absorption can occur. It is also stated that foetal hemoglobin forms methemoglobin more readily than the adult form.

According to a recent study from Germany, the primary causes of toxicity are an elevated nitrate concentration and the presence of an unphysiologic amount of nitrite-forming bacteria, especially in the upper portion of the digestive tract. Members of the coliform group and the genus Clostridium are capable of reducing nitrate to nitrite. In infants whose diet is mainly carbohydrate, it is believed that the coliform organisms are the group responsible; organisms capable of reducing nitrite to nitrogen are not normally present in the infant. Careful measurement of a number of other constituents in 23 offending well waters, nitrite, ammonia, chloride, and organic substances, failed to reveal a casual relation of these substances to the injury.

There are no reports of methemoglobinemia in infants fed water from public water supplies in the United States, although levels of nitrate in some may be routinely in excess of 45 mg/1. This may

indicate that well water for analysis has often been improperly sampled or that some other as yet unknown factor is involved. Practically nothing is known of the variation in nitrate concentration in the same well. Because samples associated with injury are taken after injury occurs, it is conceivable that this delay has resulted in failure to measure truly injurious concentrations.

Sodium nitrate has been fed to rats for a lifetime without adverse effects at levels below 1 percent (10,000 ppm) in the diet; 2 dogs tolerated for 105 and 125 days, respectively, 2 percent nitrate in the diet without effects on blood or other adverse effects.

Nitrite is equally dangerous in water supplies. Although concentrations that occur naturally are generally of no health significance, nevertheless, they may enter water supplies inadverently as a result of intentional addition to private supplies as anticorrosion agents.

A limit of 200 ppm of nitrite (or nitrate) in "corned" products has been set by Federal regulation on the basis that 100g corned beef could convert maximally from 10-40g hemoglobin to methemoglobin (1.4-5.7 percent of total hemoglobin). Adult human blood normally contains on the average of 0.7 percent methemoglobin; the blood of "heavy" smokers may contain 7-10 percent carboxyhemoglobin, another blood pigment conversion product incapable of transporting oxygen. Carbon monoxide in urban atmosphere adds perceptibly to the total inactive pigment. The summated blood pigment conversion products represent about the maximum tolerated without headache.

Because of the great difference in molecular weight between sodium nitrite, 69, and hemoglobin, 64,000, small increments of nitrite produce large quantities of methemoglobin (1g nitrite converts 460-1850g hemoglobin). The margin of safety is still further narrowed in infants whose blood volume is small, their total blood hemoglobin is decreasing after birth (from 17-20g to 10.5-12g) and their foetal hemoglobin is more readily converted to methemoglobin.

An instance of nitrite poisoning of children has been reported. The children ate frankfurters and bologna containing nitrite considerably in excess of the 200 ppm permitted.

Evidence in suport of the recommended limit for nitrite is given in detail by Walton in a survey of the reported cases of nitrate poisoning of infants in this country to 1951. The survey shows that no cases of poisoning were reported when the water contained less than 10 mg/1 nitrate nitrogen. Walton notes, however, that in many instances the samples for analysis were not obtained until several months after the occurrence of the poisoning.

In light of the above information and because of the uncertainty introduced by tardy analyses, the frequent lack of attention to possible interfering factors in the analysis, the health of the infant, and the uncertain influence of associated bacterial pollution, 10 mg nitrate nitrogen (or 45 mg nitrate) per liter of water is a limit which should not be exceeded.

At present there is no method of economically removing excessive amounts of nitrate from water. It is important, therefore, for health authorities in areas in which nitrate content of water is known to be in excess of the recommended limit to warn the population of the potential dangers of using the water for infant feeding and to inform them of alternative sources of water that may be used with safety.

Limits and Ranges Related to Nitrate Water Standard

Average concentration adult human blood: 10 ug nitrate/100 ml (0.1 ppm).

Average daily urinary nitrate excretion: 500 mg (mainly from vegetables).

Strained baby foods: 0 (squash, tomatoes)—833 pm nitrate (spinach).

Green vegetables: 50 ppm nitrate (asparagus, dry weight), 3,600 ppm nitrate (spinach, dry weight).

Limit of nitrite (or nitrate) permitted in meat (or fish) products by Federal regulation: 200 ppm.

PHENOLS

The term "phenols" is understood to include cresols and xylenols. Both the International Drinking Water Standards and those of the U.S. Public Health Service of 1946 recommended a limit of 1 ug/1 of phenol in water. This limit is set because of the undesirable taste often resulting from chlorination of waters containing extremely low concentrations of phenol. Phenol concentrations of 5 mg/1 or more are injurious to fish, whereas 1 mg/1 or less will not seriously affect most fish. Concentrations from 15-1,000 mg/1 in the drinking water were reported without observable effect on rats for extended periods; 5,000 mg/1 appeared likewise to exert no effect on digestion, absorption, or metabolism, but 7,000 mg/1 arrested growth and resulted in many stillbirths. Thus, concentrations injurious to health are far removed from those which impart unpleasant taste or affect fish. Phenol is largely detoxified in the mammalian body by conjugation to far less toxic substances.

Although additional information has been developed since the 1946 Standard was set, its nature indicates no need of a change in the former limit for phenols 0.001 mg/1 (1 ug/1).

SELENIUM

The presence of selenium in water has heretofore been a matter of regional importance. The fact

that it is now recognized as being toxic to both man and animals makes it essential that limits be set for all water intended for human consumption.

Selenium is known to produce "alkali disease" in cattle, and its effects, like those of arsenic, may be permanent. Recent reports indicate also that selenium may increase the incidence of dental caries in man. Of greater importance in limiting the concentration of selenium is its potential carcinogenicity. Rats fed a diet containing varying concentrations of selenium (3 to 40 mg/1) showed toxic effects at all levels, the outstanding pathologic lesion being hepatic cell tumors.

From very limited information concentrations of selenium in water considered safe for man have been found toxic for fish.

In view of the potential seriousness of above reported effects, it is recommended that the limits for selenium be lowered from its present value of 0.06 mg/1 to 0.01 mg/1 and concentrations in excess of this lower value be used as grounds for rejection of the supply.

SILVER

The need to set a water standard for silver (Ag) arises from its intentional addition to waters for disinfection. The chief effect of silver in the body is cosmetic, which consists of a permanent blue-grey discoloration of the skin, eyes, and mucous membranes which is as unsightly and disturbing to the observer as to the victim. The amount of colloidal silver required to produce this condition (argyria, argyrosis), and which would serve as a basis of determining the water standard, is not known, but the amount of silver from injected Ag-arsphenamine, which produces argyria is precisely known. This value is any amount greater than 1 gram of silver, 8g Ag-arsphenamine in an adult.

From a review of more than 200 cases of argyria, the following additional facts were derived. Most common salts of silver produce argyria when taken by mouth or by injection. There is a long-delayed appearance of discoloration. No case has been uncovered that has resulted from an idiosyncrasy to silver. There was, however, considerable variability in predisposition to argyria: the cause of this is unknown but individuals concurrently receiving bismuth medication developed argyria more readily. Although there is no evidence that gradual deposition of silver in the body produces any significant alteration in physiologic function, authorities are of the opinion that occasional mild systemic effects from silver may have been overshadowed by the striking external changes. In this connection, there is a report of implanted silver amalgams resulting in localized argyria restricted to the elastic fibers and capillaries. The histopathologic reaction resembled a blue nevus simulating a neoplasm with filamentous structures and globular masses. Silver

affinity for elastic fibers had been noted a half-century earlier.

A study of the metabolism of silver from intragastric intake in the rat using radio-silver in carrier-free tracer amounts showed absorption to be less than 0.1-0.2 percent of the silver administered; but this evidence is inconclusive because of the rapid elimination of silver when given in carrier-free amounts. Further study indicated, however, that silver is primarily excreted by the liver. This would be particularly true if the silver is in colloidal form. Silver in the body is transported chiefly by the blood stream in which the plasma proteins and the red cells carry practically all of it in extremely labile combinations. The half-time of small amounts of silver in the blood stream of the rat was about 1 hour. A later report, using the spectrographic method on normal human blood, showed silver unmistakably in the red blood cell and questionably in the red cell ghosts and in the plasma. Once silver is fixed in the tissues, however, negligible excretion occurs in the urine.

A study of the toxicologic effects of silver added to drinking water of rats at concentrations up to 1,000 ug/1 (nature of the silver salt unstated) showed pathologic changes in kidneys, liver, and spleen at 400, 700, and 1,000 ug/1.

A study of the resportion of silver through human skin using radio-silver Ag^m has shown none passing the dermal barrier from either solution (2 percent $AgNO_3$) or ointment, within limits of experimental error (± 2 percent). This would indicate no significant addition of silver to the body from bathing waters treated with silver.

Great uncertainty, however, currently surrounds any evaluation of the amount of silver introduced into the body when silver-treated water is used for culinary purposes. It is reasonable to assume that vegetables belonging to the family Brassicaceae, such as cabbage, turnip, cauliflower, and onion, would combine with residual silver in the cooking water. The silver content of several liters of water could thus be ingested.

Despite these uncertainties and the present lack of appropriate drinking water studies, it is possible to derive a tentative drinking water standard for silver by using silver deposited in excess of 1g in the integument of the body as an end point that must not be exceeded. Assuming that all silver ingested is deposited in the integument, it is readily calculated that 10 ug/1 could be ingested for a lifetime before 1g silver it attained from 2 liters water intake per day; 50 ug/1 silver could be ingested approximately 27 years without exceeding silver deposition of 1g.

Because of the evidence that silver, once absorbed, is held indefinitely in tissues, particularly the skin, without evident loss through usual channels of elimination or reduction by transmigration to other

body sites; and because of the probable increased absorbability of silver as silver-bound sulfur components of food cooked in silver-treated waters, the intake for which absorption was reported in 1940 to amount to 60–80 ug per day; and because of the above calculation, a concentration in excess 50 ug/1 is grounds for rejection of the supply.

ZINC

Limits for concentrations of zinc in drinking waters have been established as follows: (a) USPHS Drinking Water Standards (1946), 15 mg/1; (b) Ohio and North Dakota, 1 mg/1; (c) International Drinking Water Standards (1958), permissible—5 mg/1 and excessive—15 mg/1; (d) various South American Countries, 5 to 15 mg/1.

Zinc is an essential and beneficial element in human metabolism. The daily requirement for pre-school-age children is 0.3 mg Zn/kg. Total zinc in the adult averages 2g. Zinc content of human tissues ranges from 10–200 ppm wet weight, the retina of the eye and the prostate containing the largest concentrations (500–1,000 ppm). Three percent of all blood zinc is in the white blood cells. The daily adult human intake averages 10–15 mg; excretion of zinc averages about 10 mg daily in the feces and 0.4 mg in the urine. Zinc deficiency in animals leads to growth retardation that is overcome by adequate dietary zinc. The activity of several body enzymes is dependent on zinc.

A group of individuals stationed at a depot used a drinking water supply containing zinc at 23.8 to 40.8 mg/1 and experienced no known harmful effects. Communities have used waters containing from 11–27 mg/1 without harmful effects. Another report stated spring water containing 50 mg/1 was used for a protracted period without noticeable harm. On the other hand, another supply containing approximately 30 mg/1 was claimed to cause nausea and fainting.

Zinc salts act as gastrointestinal irritants. Although the illness is acute, it is transitory. The emetic concentration range in water is 675–2,280 mg/1. In tests performed by a taste panel, 5 percent of the observers were able to distinguish between water containing 4 mg/1 (when present as zinc sulfate) and water containing no zinc salts. Soluble zinc salts at 30 mg/1 impart milky appearance to water, and at 40 mg/1, a metallic taste.

Inasmuch as zinc in water does not cause serious effects on health but produces undesirable esthetic effects, it is recommended that concentrations of zinc be kept below 5 mg/1.

Cadmium and lead are common contaminants of zinc used in galvanizing. Assuming that zinc is dissolved from galvanized water pipe no less than cadmium, dissolution of zinc to produce 5 mg/1 would be accompanied by something less than the allowable 0.01 mg cadmium per liter when cadmium contamination of the zinc is as high as 0.03 percent. Likewise, lead concentrations would likely be increased by something less than the allowable 0.05 mg/1 when lead contamination of the zinc is as high as 0.6 percent.

Limits and Ranges Relative to Zinc Water Standards

Food—Milk, 4 mg/1

Egg (hen)—1 mg

Cd content of galvanized pipe: 0.014–0.04 percent. Average 0.03 percent.

Pb content of galvanized pipe: 0.24–0.6 percent. Average 0.45 percent.

Urban air concentration: Average 2 ug/m³.

Concentrations toxic to fish: 0.3–4 mg/1, depending on degree of water hardness.

Drinking water containing 50 mg/1 (as sulfate) was not harmful to rats which used it for 6 weeks.

E—RADIOACTIVITY

The effects of radiation on human beings are viewed as harmful and any unnecessary exposure to radiation should be avoided. In this discussion we are concerned with radiation from radioactive materials in the environment, particularly in water, food, and air.

The development of the nuclear industry has been attended by a small, unavoidable increase of radioactivity in the environment. Nuclear weapons testing causes an increase of radioactivity from fallout. Exposure of human beings to environmental sources of radiation should be minimized insofar as is technically and economically feasible.

The Federal Radiation Council has provided guidance for Federal agencies conducting activities designed to limit exposure of individuals of population groups to radiation from radioactive materials deposited in the body as a result of their occurrence in the environment.

The following recommendation of the Federal Radiation Council is considered especially pertinent in applying these Standards:

"There can be no single permissible or acceptable level of exposure without regard to the reason for permitting the exposure. It should be general practice to reduce exposure to radiation, and positive effort should be carried out to fulfill the sense of these recommendations. It is basic that exposure to radiation should result from a real determination of its necessity."

The Federal Radiation Council criteria have been observed in establishing the limits for radioactivity in the Drinking Water Standards. It should be noted that these Federal Radiation Council guides apply to normal peacetime operations.

The Federal Radiation Council guides are predicated upon three ranges of daily intake of radioactivity. For each range, a measure of control action was defined, which represented a graded scale of control procedures. These are shown by the following table:

Table I.—Graded scales of action

Ranges of transient rates of daily intake	Graded scale of action
Range I	Periodic confirmatory surveillance as necessary.
Range II	Quantitative surveillance and routine control.
Range III	Evaluation and application of additional control measures as necessary.

The Federal Radiation Council further defined the action to be taken by stating that: "Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II." Furthermore, they recommended, with respect to Range III, that "Control actions would be designed to reduce the levels to Range II or lower and to provide stability at lower levels."

The radionuclide intake ranges recommended are the sum of radioactivity from air, food, and water. Daily intakes were prescribed with the provision that dose rates be averaged over a period of one year. The range for specific radionuclides recommended by the Federal Radiation Council are shown in the following table:

Table II.—Ranges of transient rates of intake (micromicrocuries per day) for use in graded scale of actions summarized in table I

Radionuclides	Range I	Range II	Range III
Radium-226	0-2	2-20	20-200
Iodine-131 [1]	0-10	10-100	100-1,000
Strontium-90	0-20	20-200	200-2,000
Strontium-89	0-200	200-2,000	2,000-20,000

[1] In the case of iodine-131, the suitable sample would include only small children. For adults, the RPG for the thyroid would not be exceeded by rates of intake higher by a factor of 10 than those applicable to small children.

The Advisory Committee, in considering limits which should be established for drinking water, recommended limits for only two of the above nuclides, Radium-226 (3 $\mu\mu c$ per liter) and Strontium-90 (10 $\mu\mu c$ per liter). Iodine-131 is not found in significant quantities in public water supplies frequently enough to call for routine monitoring and Strontium-89 levels are not likely to be significant unless Strontium-90 levels also are high.

In the case of Radium-226, above-average levels of intake generally occur only in unusual situations where the drinking water contains naturally occurring Radium-226 in greater than average amounts, as in the case of certain ground waters, or from the pollution of the supply by industrial discharges of waste containing radium. With this in mind, a limit of 3 $\mu\mu c$/liter has been set for Radium-226 in drinking water. If one assumes a daily intake of such drinking water of about 2 liters per day, this would result in a daily intake from water of 6 $\mu\mu c$ which falls in the lower portion of Range II in the above table. If there is evidence that Radium-226 from sources other than water is greater than usual, levels may have to be reduced below the above limit using the guides established by the Federal Radiation Council.

The principal source of Strontium-90 in the environment to date has been due to fallout from weapon tests, and human intake of Strontium-90 to date has been primarily from food. In recognition of this fact, the limit for Strontium-90 in water has been set at 10 $\mu\mu c$/liter, a limit substantially higher than the highest level found in public water supplies to date.

The Standards recognized the need to provide guidance for those situations where the limits are exceeded. In these instances, the Standards provide for the continued acceptance of the water supply if radioactivity from all other sources in addition to that from the water does not exceed intake levels recommended by the Federal Radiation Council for control action (the upper limit of Range II). It is essential in such instances for the certifying authority to determine with reasonable confidence that this latter condition is met.

Although a great variety of radionuclides may be present in drinking water, it has not been considered necessary to establish limits for general application to water supplies for other than the above two at this time. If significant concentrations of radioactivity are found in drinking water, an effort should be made to determine the radionuclides present and, where appropriate, to reduce their concentrations as much as feasible.

In assessing the hazard of radionuclides for which limits have not been set in these Standards, or for which guidance has not yet been provided by the Federal Radiation Council, it is suggested that the values (MPCw for the 168-hour week) in table I, of the report of the International Commission on Radiological Protection or the National Committee on Radiation Protection, adjusted by a factor appropriate for exposure of the general population, be

used. When mixtures of radionuclides are present the permissible concentration of any single nuclide must be reduced by an amount determined through applicable calculations in these reports.

In these Standards an upper limit of 1,000 c per liter of gross beta activity (in the absence[1] of alpha emitters and Strontium-90) has been set. If this limit is exceeded the specific radionuclides present must be identified by complete analysis in order to establish the fact that the concentrations of nuclides will not produce exposures above the recommended limits established in the Radiation Protection Guides.

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[1] "Absence" is intended to mean a negligibly small fraction of the limits established for these nuclides and the limit for unidentified alpha emitters is taken as the listed limit for Radium 226.